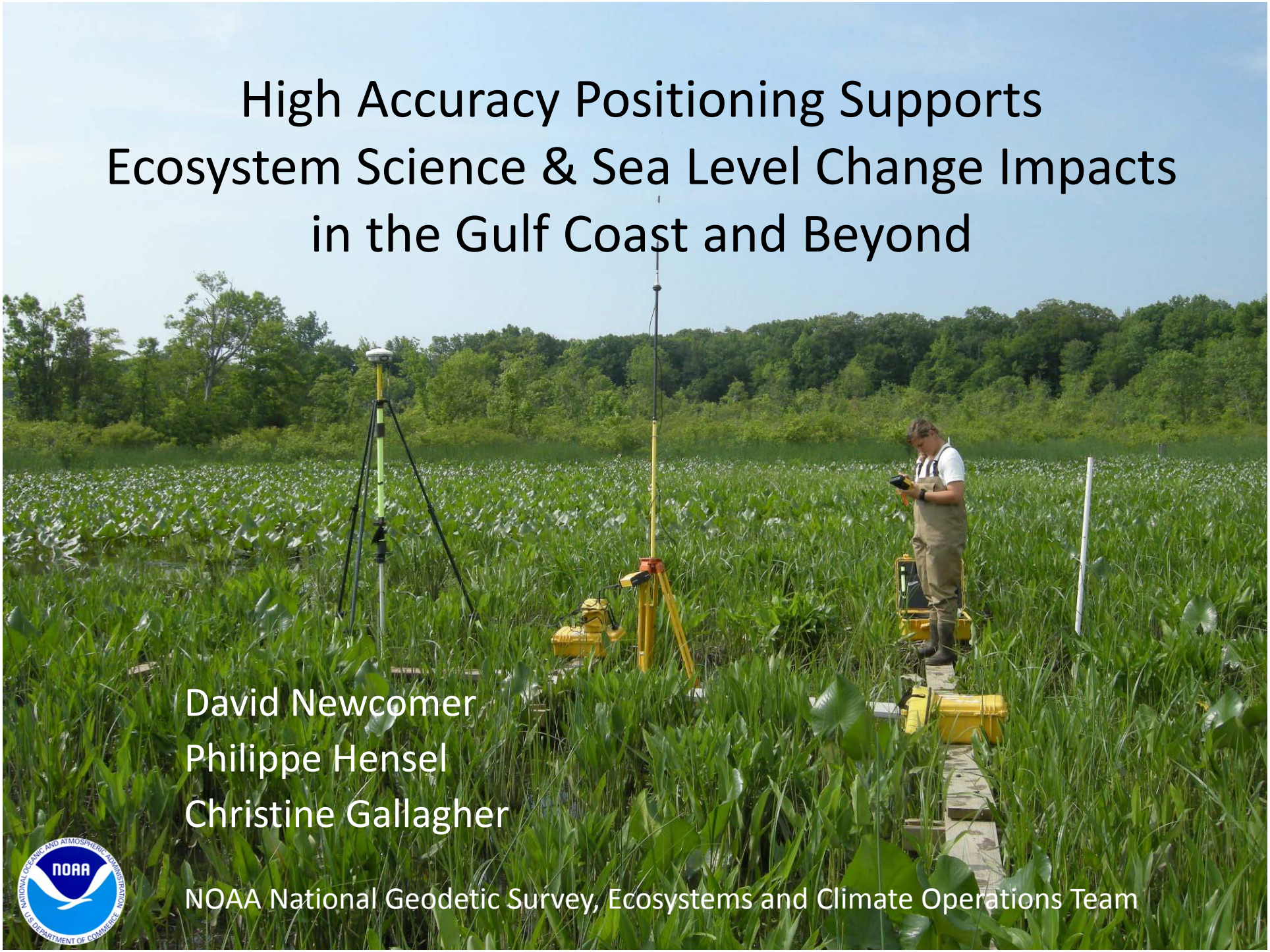
High Accuracy Positioning Supports Ecosystem Science & Sea Level Change Impacts in the Gulf Coast and Beyond



David Newcomer
Philippe Hensel
Christine Gallagher

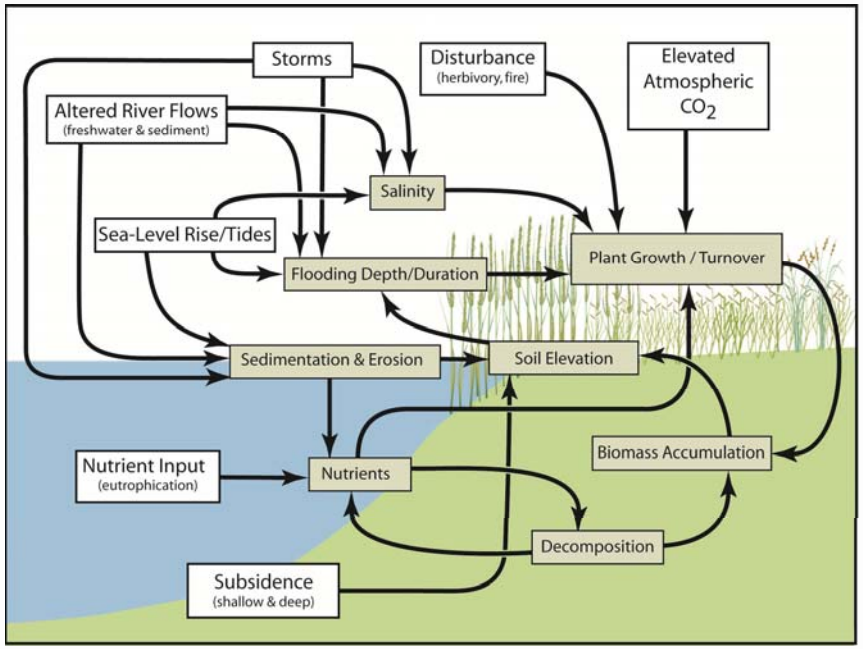
NOAA National Geodetic Survey, Ecosystems and Climate Operations Team

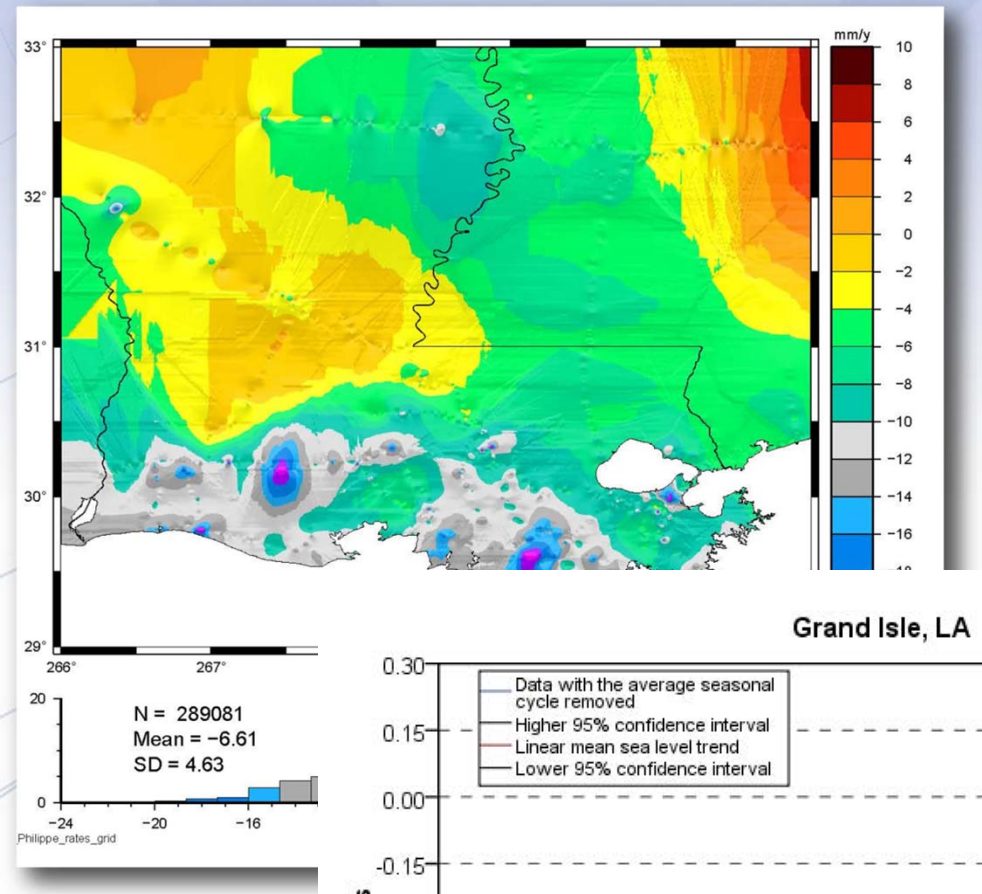
Why Millimeters Matter

- Small changes in elevation and sea levels can lead to large changes in flooding
  - Flooding causes damage to coastal communities and built infrastructure (e.g. roads, houses)
  - Changes in frequency and duration of inundation in natural environments can damage critical ecosystems

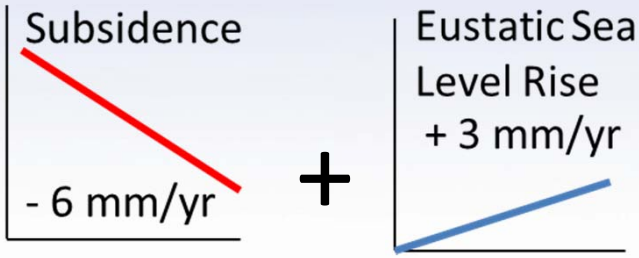
Why Millimeters Matter

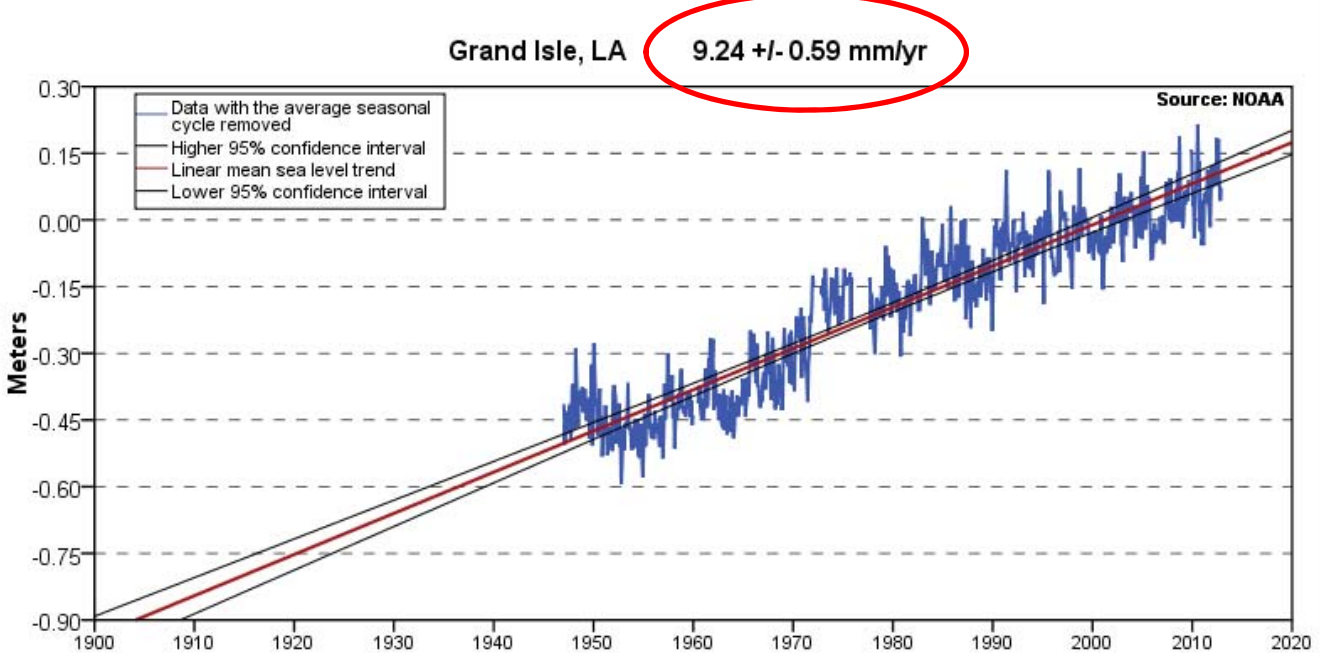
- Most vertical changes occur on the scale of millimeters per year
  - subsidence
  - eustatic sea level rise
  - sedimentation & erosion
  - decomposition
  - biomass accumulation





- Processes can combine to cause centimeter per year scale changes





Why Millimeters Matter

- Small changes in elevation and sea levels can lead to large changes in flooding
- Most vertical changes occur on the scale of millimeters per year

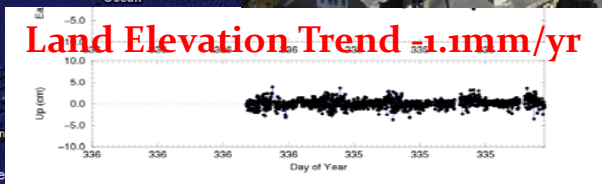
Coastal habitats change in response to changing water levels
To better understand mechanisms of change,
and to better respond to a changing environment,
we need to be able to connect our habitat observations to local water levels at the millimeter scale

The National Spatial Reference System

- "Passive" marks

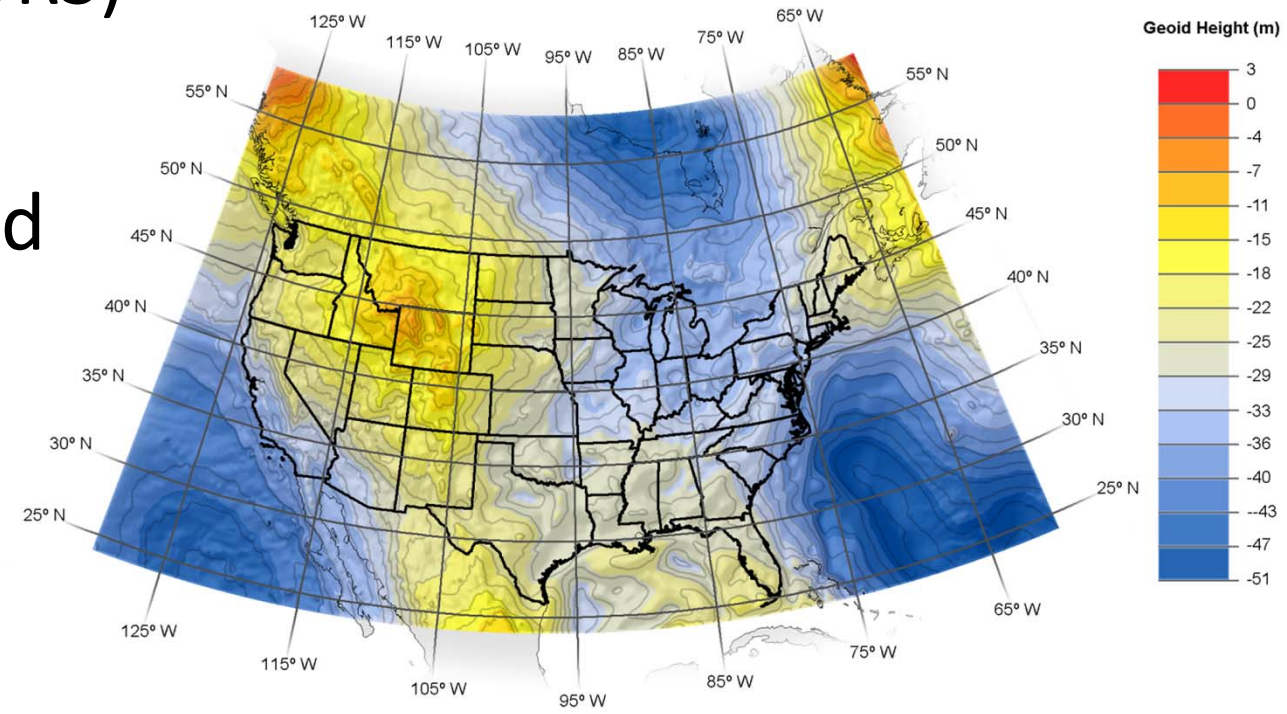
The National Spatial Reference System

- "Passive" marks
- Continuously Operating GPS Reference Stations (CORS)

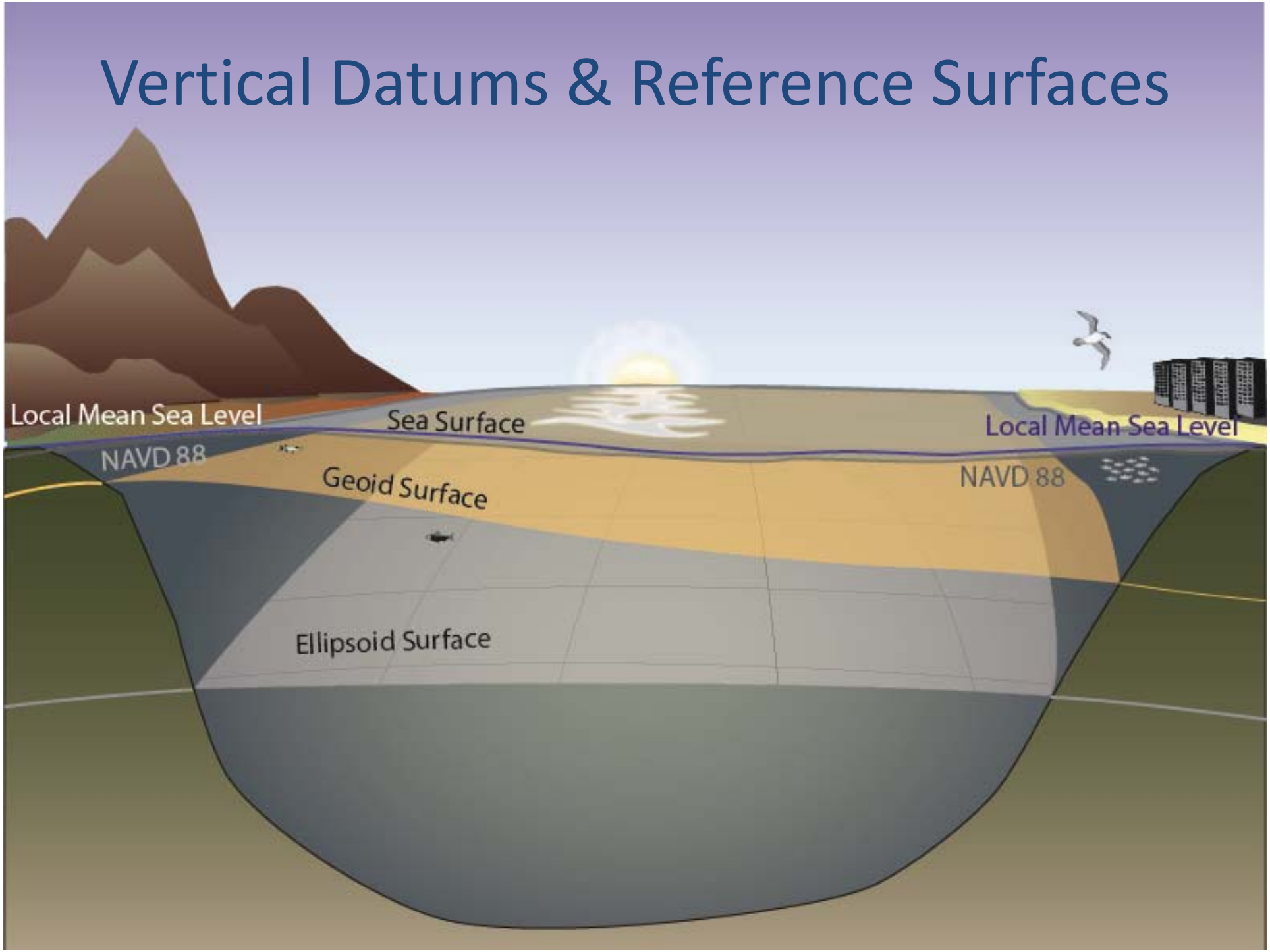


The National Spatial Reference System

- "Passive" marks
- Continuously Operating GPS Reference Stations (CORS)
- Gravity
- Hybrid Geoid



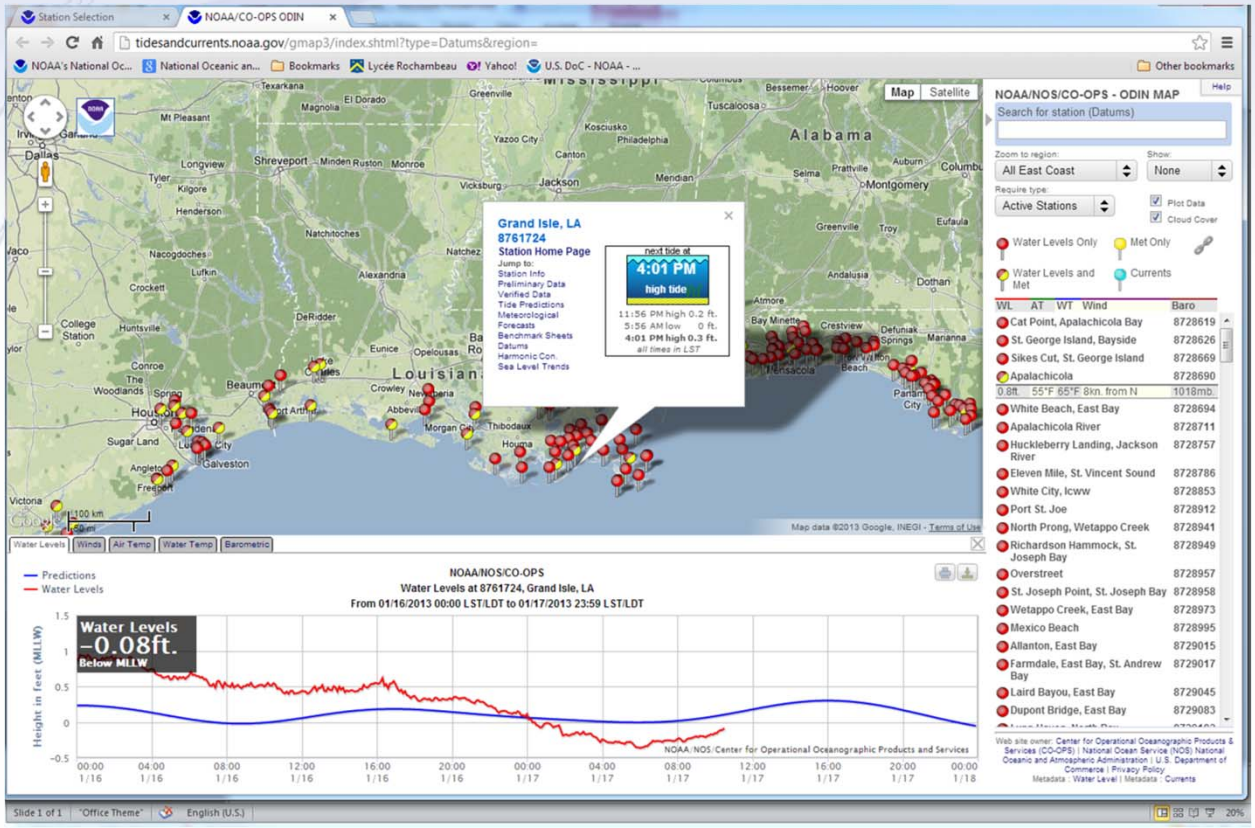
Vertical Datums & Reference Surfaces



Why Millimeters Matter

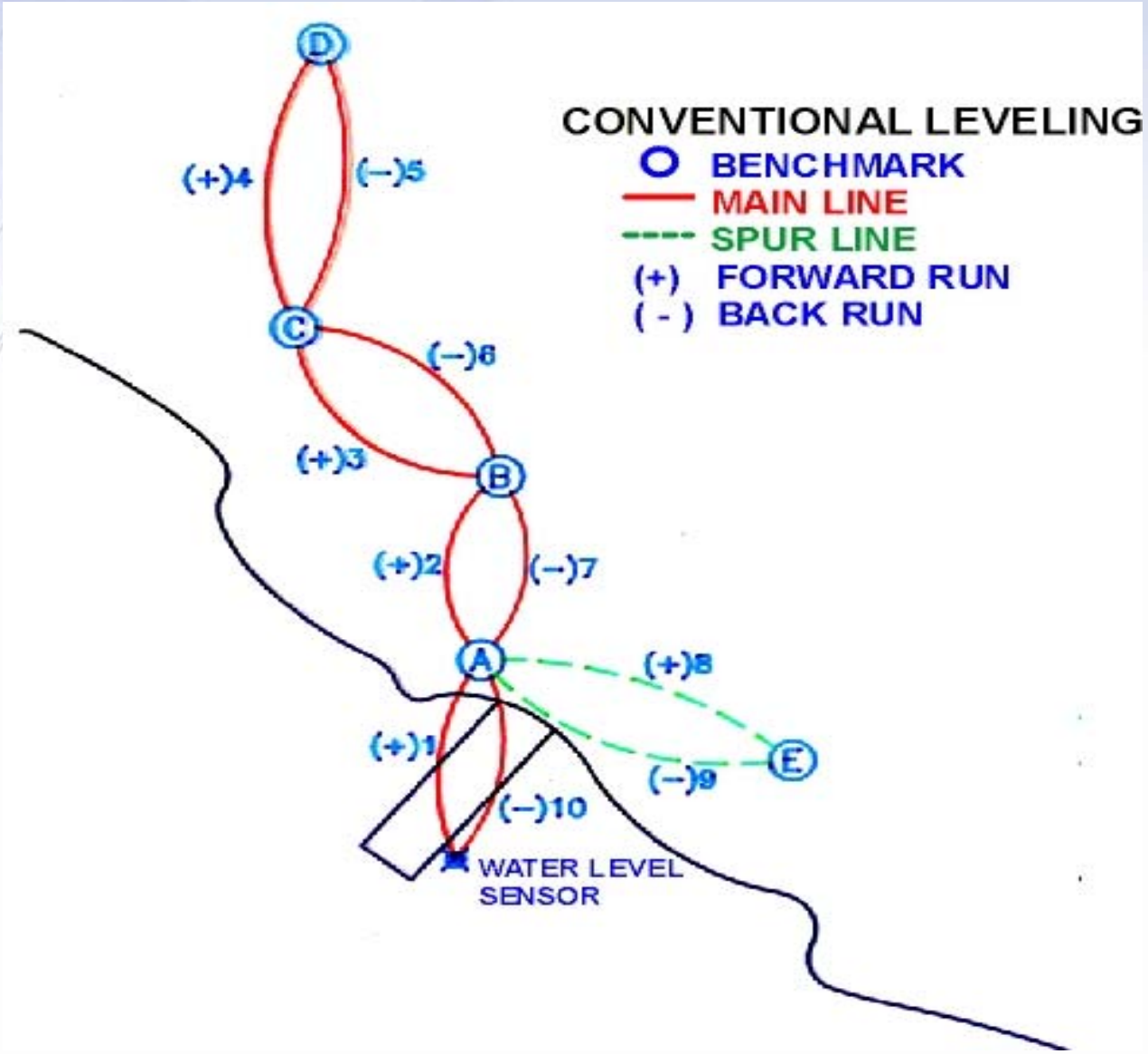
Surface too low: too much flooding → plant death → mud flat

National Water Level Observation Network (NWLON)



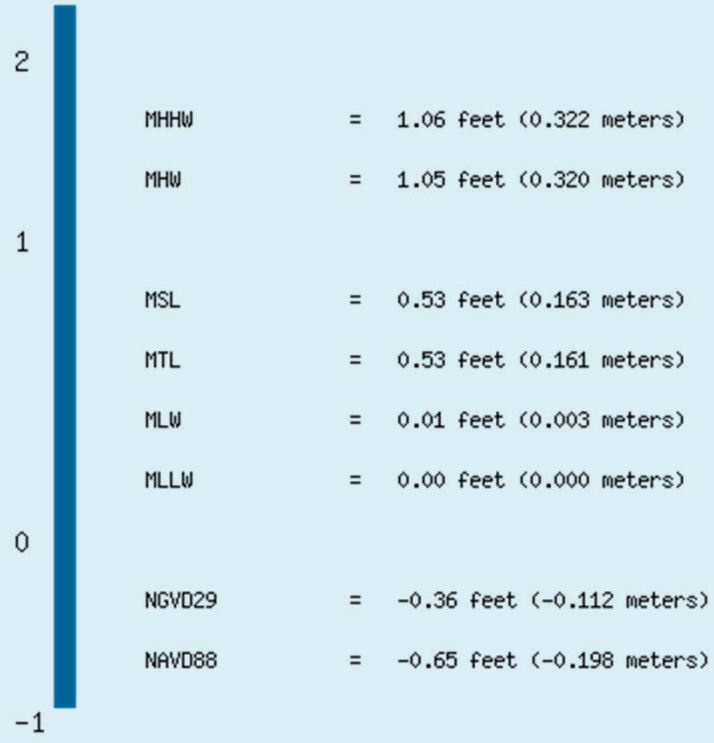
National Water Level Observation Network (NWLON)

National Water Level Observation



Elevation Information

PID: AT0687
VM: 817
Station ID: 8761724
Epoch: 2002-2006
Date: Mon Jan 21 22:23:22 EST 2013



MHHW 0.322 m

[above arbitrary station datum]

21 cm difference

NGVD 29 -0.112 m

NAVD 88 -0.198 m

8 cm difference

The NGS Data Sheet

See file dsdata.txt for more information about the datasheet.

```
PROGRAM = datasheet95, VERSION = 8.00
1         National Geodetic Survey,    Retrieval Date = JANUARY 14, 2013
 BH0297 ***********************************************************************
 BH0297  DESIGNATION -  W 191
 BH0297  PID         -  BH0297
 BH0297  STATE/COUNTY-  MS/HARRISON
 BH0297  COUNTRY     -  US
 BH0297  USGS QUAD   -  BILOXI (1992)
 BH0297
 BH0297                         *CURRENT SURVEY CONTROL
 BH0297
 BH0297* NAD 83(1986) POSITION- 30 23 52.0     (N) 088 56 19.2     (W)    HD_HELD2
 BH0297* NAVD 88 ORTHO HEIGHT -      8.384   (meters)       27.51   (feet) ADJUSTED
 BH0297* NAVD 88 EPOCH        -   2009.55
 BH0297  **This station is located in a suspected subsidence area (see below).
 BH0297
 BH0297  GEOID HEIGHT     -        -28.09   (meters)                       GEOID12A
 BH0297  DYNAMIC HEIGHT   -          8.373  (meters)       27.47   (feet) COMP
 BH0297  MODELED GRAVITY -    979,315.8    (mgal)                         NAVD 88
 BH0297
 BH0297  VERT ORDER       -  FIRST     CLASS II
 BH0297
 BH0297.The horizontal coordinates were established by autonomous hand held GPS
 BH0297.observations and have an estimated accuracy of +/- 10 meters.
 BH0297.
 BH0297 ** This station is in an area of known vertical motion.  Due to the
 BH0297 ** variability of land subsidence, uplift, and crustal motion, NGS has,
 BH0297 ** determined the orthometric heights for marks in these suspect
 BH0297 ** subsidence areas should be considered valid only at the epoch date
 BH0297 ** associated with the orthometric height.  These heights must always
 BH0297 ** be validated when used as control.  All previously superseded
 BH0297 ** orthometric heights are now considered suspect and are available
 BH0297 ** in the superseded section.  NGS does not recommend using suspect
 BH0297 ** or superseded heights as control.
 BH0297
 BH0297.The orthometric height was determined by differential leveling and
 BH0297.adjusted by the NATIONAL GEODETIC SURVEY
 BH0297.in July 2012.
 BH0297
 BH0297.The dynamic height is computed by dividing the NAVD 88
 BH0297.geopotential number by the normal gravity value computed on the
 BH0297.Geodetic Reference System of 1980 (GRS 80) ellipsoid at 45
 BH0297.degrees latitude (g = 980.6199 gals.).
 BH0297
 BH0297.The modeled gravity was interpolated from observed gravity values.
 BH0297
 BH0297;                    North         East      Units  Estimated Accuracy
 BH0297;SPC MS E      -    99,520.      289,878.      MT   (+/- 10 meters HH2 GPS)
 BH0297
 BH0297                          SUPERSEDED SURVEY CONTROL
 BH0297
 BH0297  NAVD 88 (06/15/91)     8.527   (m)            27.98    (f) SUPERSEDED  1 1
 BH0297  NGVD 29 (??/??/??)     8.489   (m)            27.85    (f) ADJUSTED    1 1
```

Height in 2009

Height in 1991

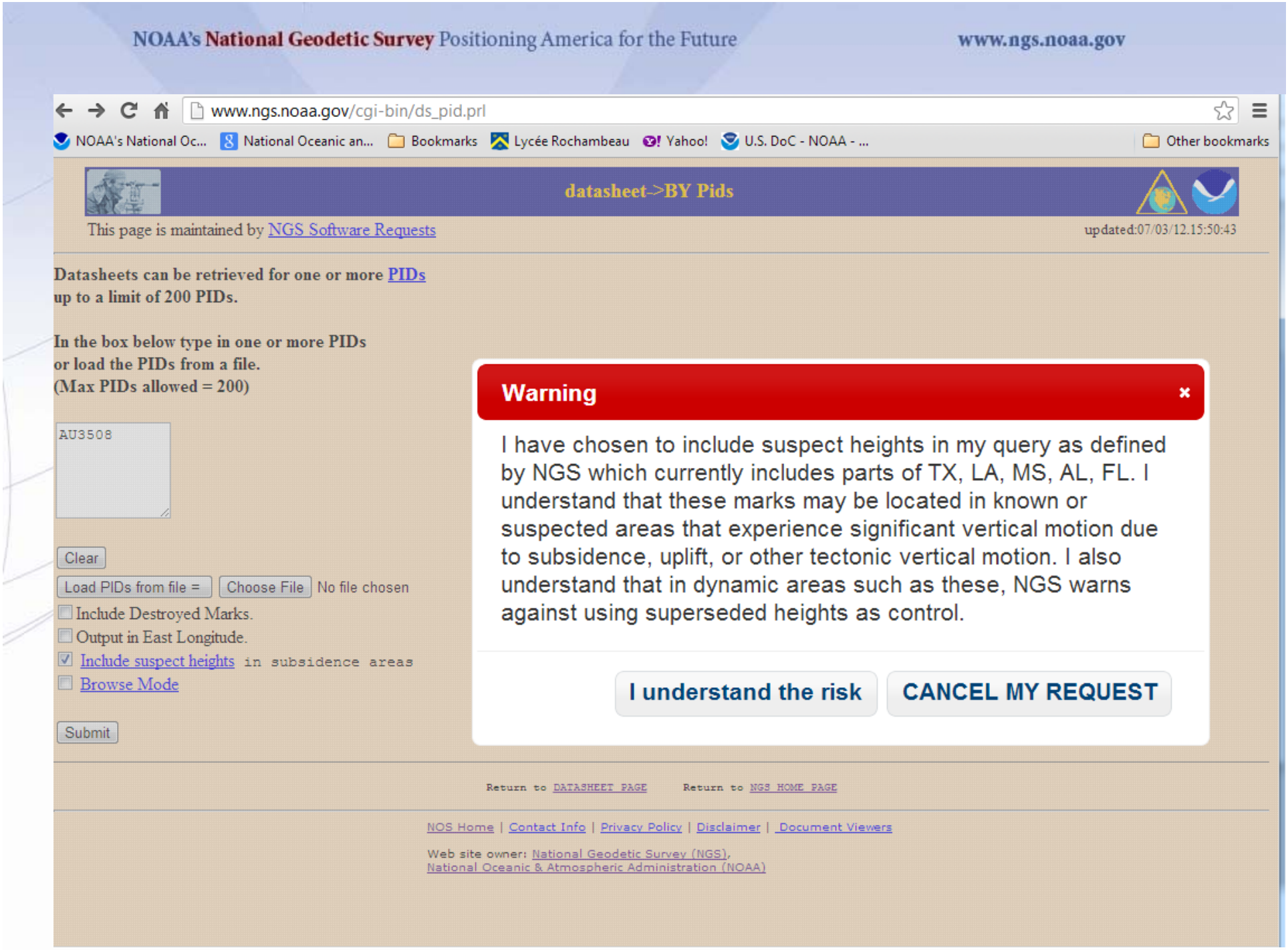
Diff = .143 m or .47 ft

www.ngs.noaa.gov

sidence

c" marks can be

Subsidence on bench mark W 191 in Biloxi MS from 1991 to 2009 (≈ 8 mm yr^{-1})


NOAA's National Geodetic Survey Positioning America for the Future
www.ngs.noaa.gov
www.ngs.noaa.gov/cgi-bin/ds_pid.prl
NOAA's National Oc...
National Oceanic an...
Bookmarks
Lycée Rochambeau
Yahoo!
U.S. DoC - NOAA - ...
Other bookmarks
datasheet->BY Pids
This page is maintained by NGS Software Requests
updated:07/03/12.15:50:43
Datasheets can be retrieved for one or more PIDs
up to a limit of 200 PIDs.
In the box below type in one or more PIDs
or load the PIDs from a file.
(Max PIDs allowed = 200)
AU3508
Clear
Load PIDs from file =
Choose File
No file chosen
Include Destroyed Marks.
Output in East Longitude.
Include suspect heights in subsidence areas
Browse Mode
Submit
Warning
I have chosen to include suspect heights in my query as defined by NGS which currently includes parts of TX, LA, MS, AL, FL. I understand that these marks may be located in known or suspected areas that experience significant vertical motion due to subsidence, uplift, or other tectonic vertical motion. I also understand that in dynamic areas such as these, NGS warns against using superseded heights as control.
I understand the risk
CANCEL MY REQUEST
Return to DATASHEET PAGE
Return to NGS HOME PAGE
NOS Home | Contact Info | Privacy Policy | Disclaimer | Document Viewers
Web site owner: National Geodetic Survey (NGS),
National Oceanic & Atmospheric Administration (NOAA)

www.ngs.noaa.gov

ence

arks can be

get

old data are

DATASHEETS

www.ngs.noaa.gov/OPUS/getDatasheet.jsp?PID=AT0685&...24071515&style=m

NOAA's National Oc... | National Oceanic an... | Bookmarks | Lycée Rochambeau | Yahoo! | Other bookmarks

SURVEY DATASHEET (Version 1.0)

PID: AT0685
Designation: 876 1724 TIDAL 11
Stamping: 11
Stability: Monument will probably hold position well
Setting: Massive retaining walls
Mark Condition: G
Description:
Observed: 2007-10-13T13:28:00Z See Also 2006-04-04
Source: OPUS - page5 1209.04

Close-up View

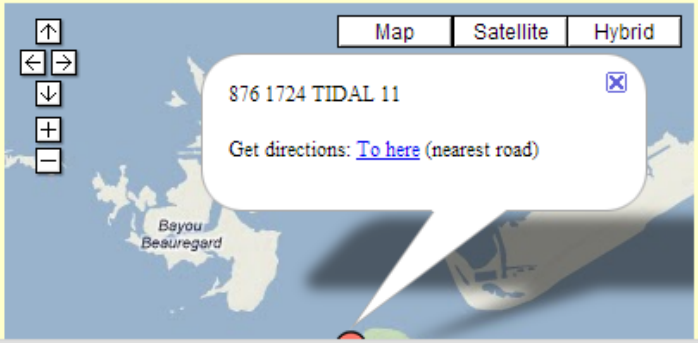
REF_FRAME:	EPOCH:	SOURCE:	UNITS:	SET	
NAD_83(2011)	2010.0000	NAVD88 (Computed using GEOID12A)	m	PROFILE	DETAILS

LAT:	29° 15' 53.27912" ± 0.001 m	
LON:	-89° 57' 27.08133" ± 0.003 m	
ELL HT:	-23.052 ± 0.003 m	
X:	4128.344 ± 0.003 m	
Y:	-5568528.197 ± 0.002 m	
Z:	3099526.928 ± 0.002 m	
ORTHO HT:	0.922 ± 0.012 m	

	UTM 15	SPC 1702(LA S)
NORTHING:	3241163.357m	85578.743m
EASTING:	795651.723m	1133712.207m
CONVERGENCE:	1.48838579°	0.68792283°
POINT SCALE:	1.00067875	1.00000764
COMBINED FACTOR:	1.00068237	1.00001126

CONTRIBUTED BY

glen
John Oswald and Associates, LLC



Grand Isle Datums.gif

Show all downloads...

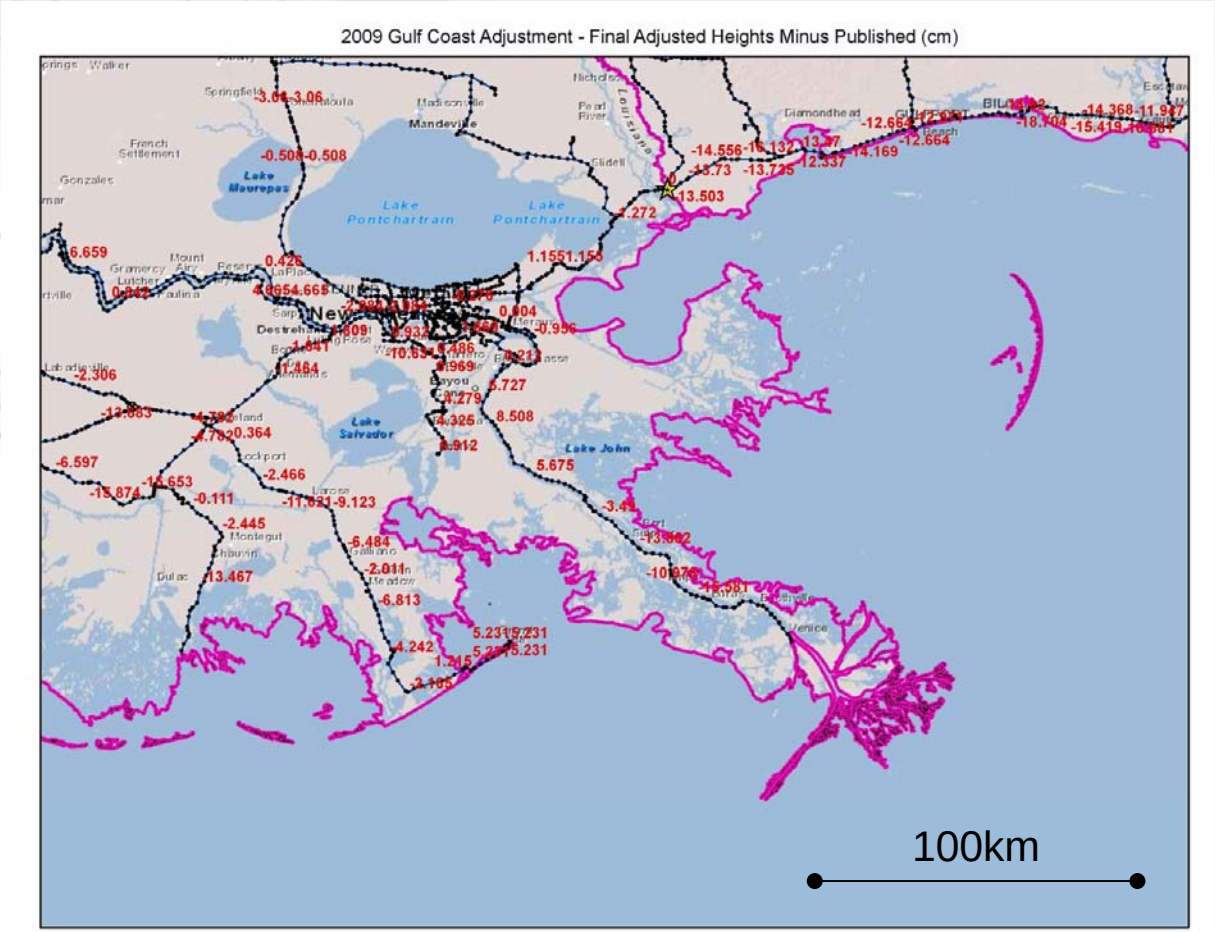
Problems with Subsidence

- Published elevations on "static" marks can be suspect over time
- NGS forces you to "accept risk" to get published heights
- Concept of "epoch" tell you how old data are
- Reference surfaces and datums need to be considered

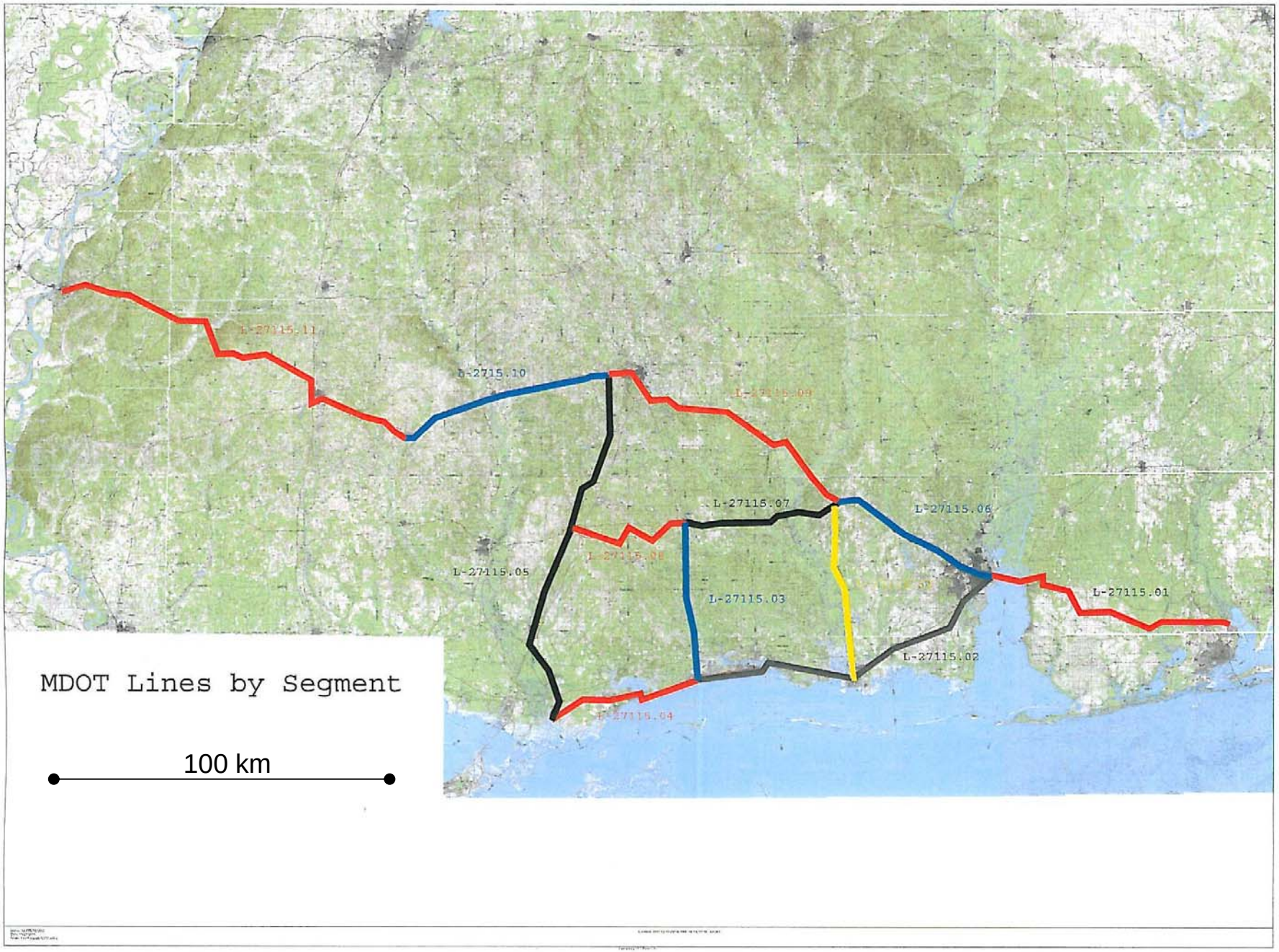
So how do I get new & updated high accuracy positions?

- Height Modernization
  - Specialized survey techniques based on GPS but also combines leveling
  - Numerous states have successfully run "Height Mod" projects to update their heights
  - This is especially attractive for extending heights to areas not amenable to leveling (islands, wetlands)

So how do I get new & updated high accuracy positions?

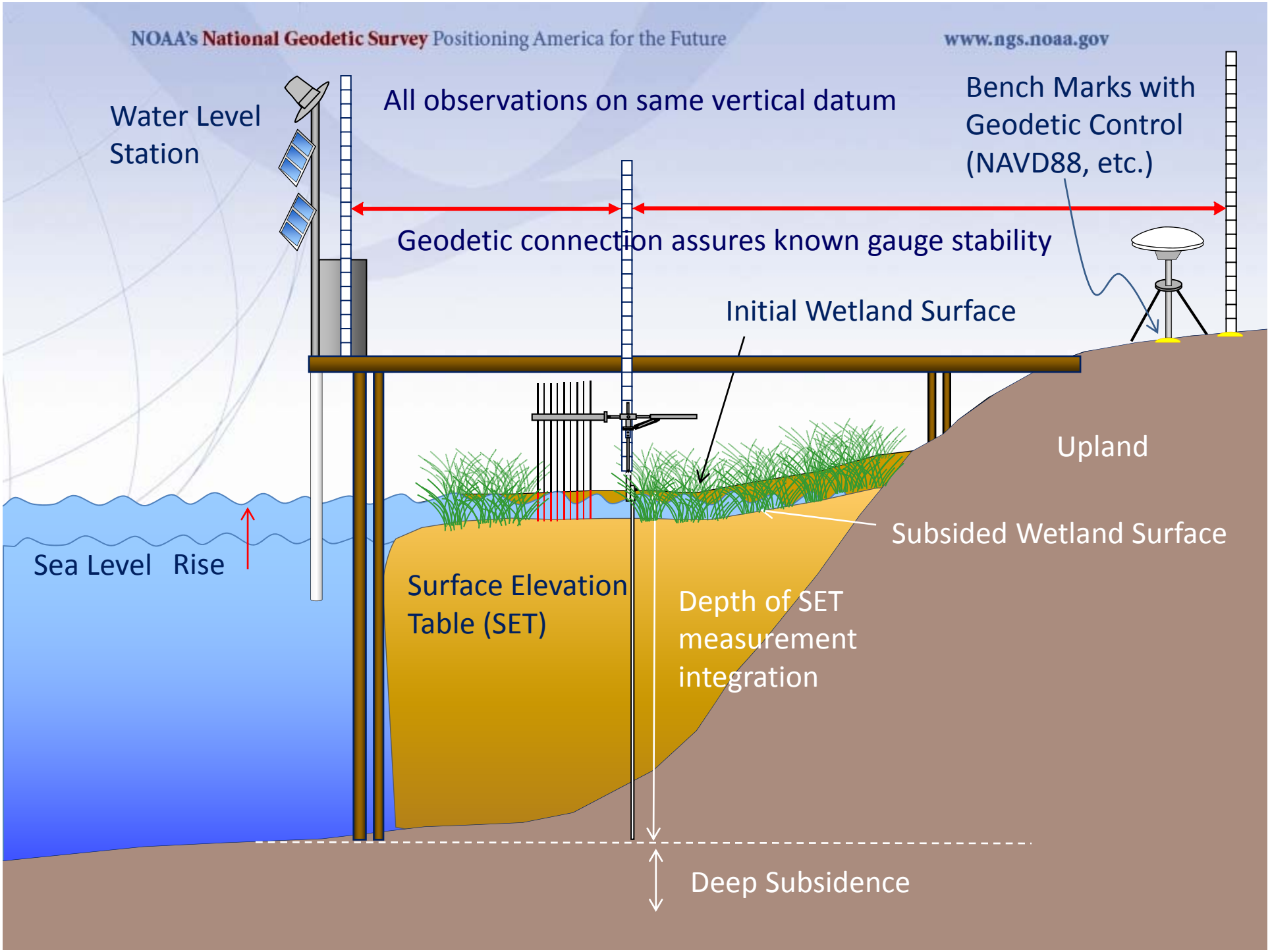


2012 Gulf Coast Adjustment: up to 10 or more cm differences!

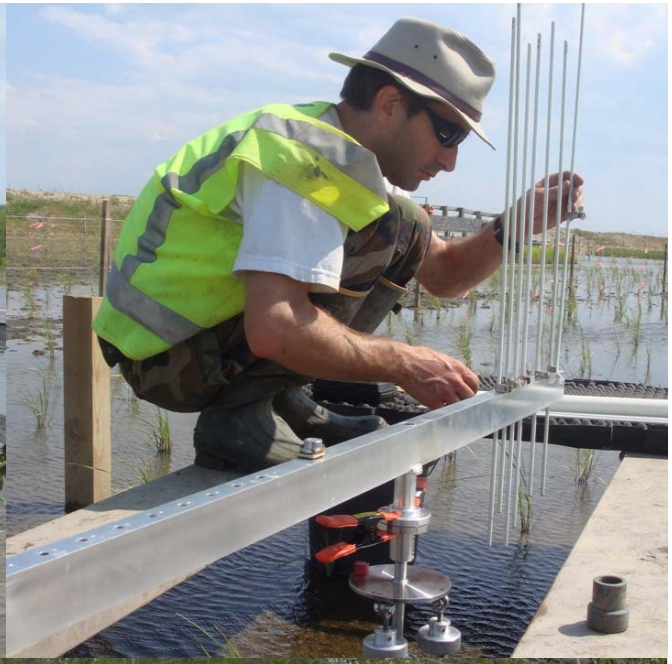

L-27115.11
L-2715.10
L-27115.07
L-27115.06
L-27115.05
L-27115.03
L-27115.01
L-27115.02
MDOT Lines by Segment
100 km

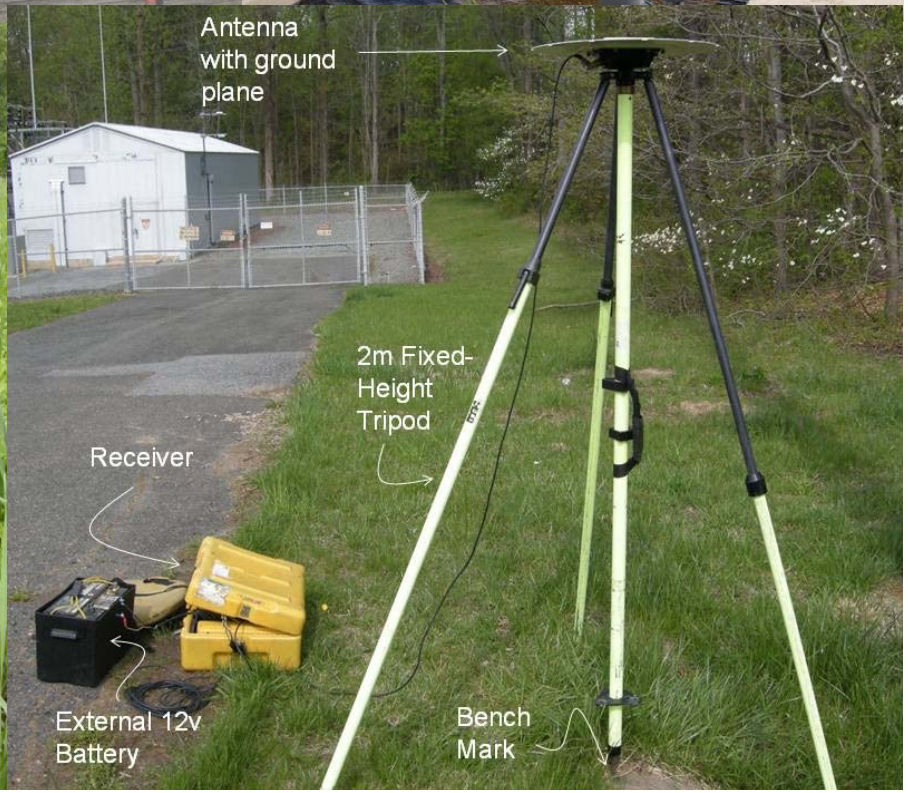
Sentinel Site Initiative

- National program to establish long term coastal ecosystem monitoring sites
- National Estuarine Research Reserve System (NERRS)
- National Park Service
- Regional Cooperatives


NOAA's National Geodetic Survey Positioning America for the Future
www.ngs.noaa.gov
Water Level Station
All observations on same vertical datum
Bench Marks with Geodetic Control (NAVD88, etc.)
Geodetic connection assures known gauge stability
Initial Wetland Surface
Upland
Subsided Wetland Surface
Sea Level Rise
Surface Elevation Table (SET)
Depth of SET measurement integration
Deep Subsidence

NERRS Sentinel Site Initiative




Antenna
with ground
plane
2m Fixed-
Height
Tripod
Receiver
External 12v
Battery
Bench
Mark

www.ngs.noaa.gov/corbin/online_learning.shtml

NOAA's National Oc... | National Oceanic an... | Bookmarks | Lycée Rochambeau | Yahoo! | Other bookmarks

NGS Online Learning Resources

National Geodetic Survey

NGS Home | About NGS | Data & Imagery | Tools | Surveys | Science & Education | Search

NGS Online Learning Resources

This page will be populated as we grow our online learning program. Click on the *Join Our Mailing List* link in the left-hand column if you would like to receive an email when new material is posted.

Here are links to the current online learning resources:

Navigation

- Corbin Training Center
- Online Learning Resources
- Upcoming Classes
- Past Classes
- Directions
- Lodging/Transportation
- Photos
- ISS Program
- Interactive Web Map

Join Our Mailing List

Contact Us

Phone: (540) 373-1243

Fax: (540) 373-4327

Email Us

Past Webinars with Audio:

Overview of DSWorld, presented February 16, 2012, by Malcolm Archer-Shee
- This page includes a link to the presentation with audio.

Real-Time Positioning -Best Methods for the Field, presented November 9, 2011, by Bill Henning
- This page includes a link to the presentation with audio, and the powerpoint file.

LiDAR and Height Modernization, a workshop held in Silver Spring, MD, August 18, 2011
- Click here to view information about the workshop.
- Click here to view videos of the presentations.

Introduction to Geodetic and Tidal Vertical Datums, presented August 16 and 18, 2011, by Dave Minkel, Michael Michalski and Scott Duncan
- This page includes a link to the presentations with audio, and the powerpoint files.

Update on Gravity for the Redefinition of the American Vertical Datum (GRAV-D), presented May 9, 2011, by Dr. Theresa Deihl
- This page includes a link to the presentation with audio.

Modernization of the National Spatial Reference System, presented April 18, 2011, by Dave Doyle
- This page includes a link to the presentation with audio, and the powerpoint file.

State Plane Coordinates, presented December 8, 2010, by Dave Doyle
- This page includes a link to the presentation with audio, and the powerpoint file.

GPS-Derived Heights, Focus on NGS 59 Guidelines, presented May 13, 2010, by Dave Zilkoski (former NGS Director)
- This page includes a link to the presentation with audio, and the powerpoint file.

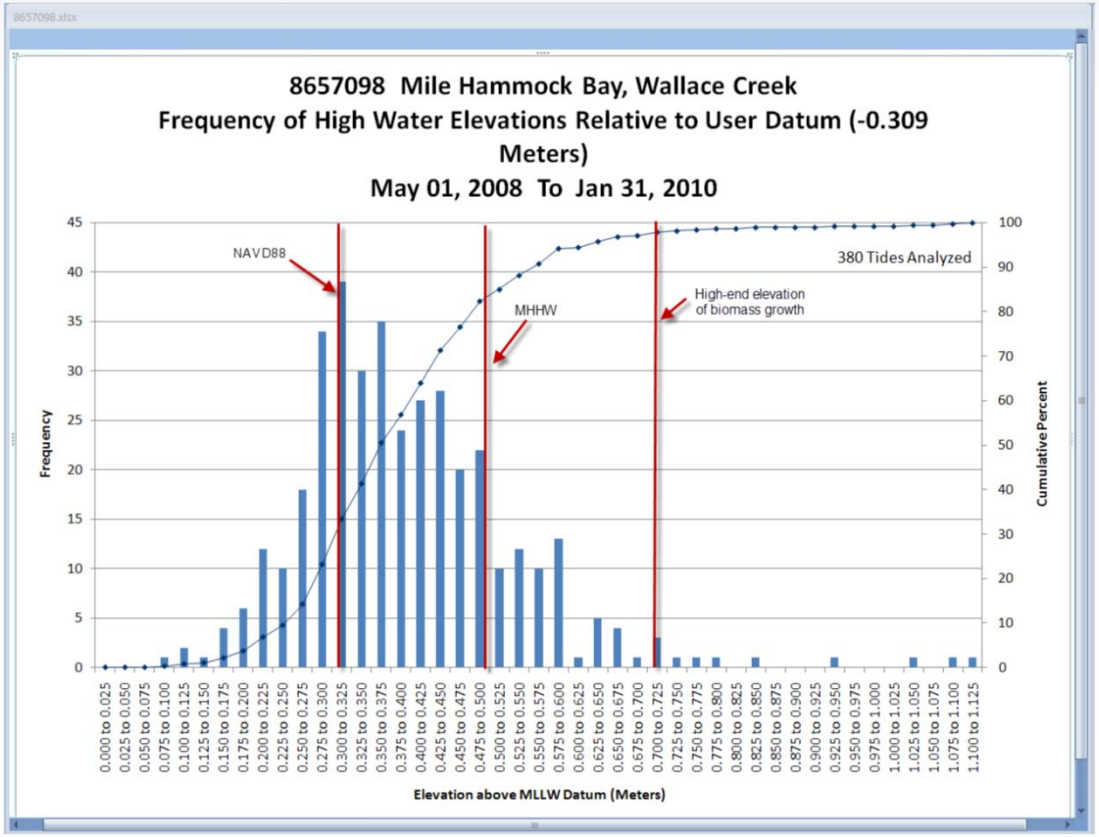
Introduction to Geodetic and Tidal Vertical Datums, presented March 2-3 and 9th, 2010 by Dave Doyle

Where do I start?

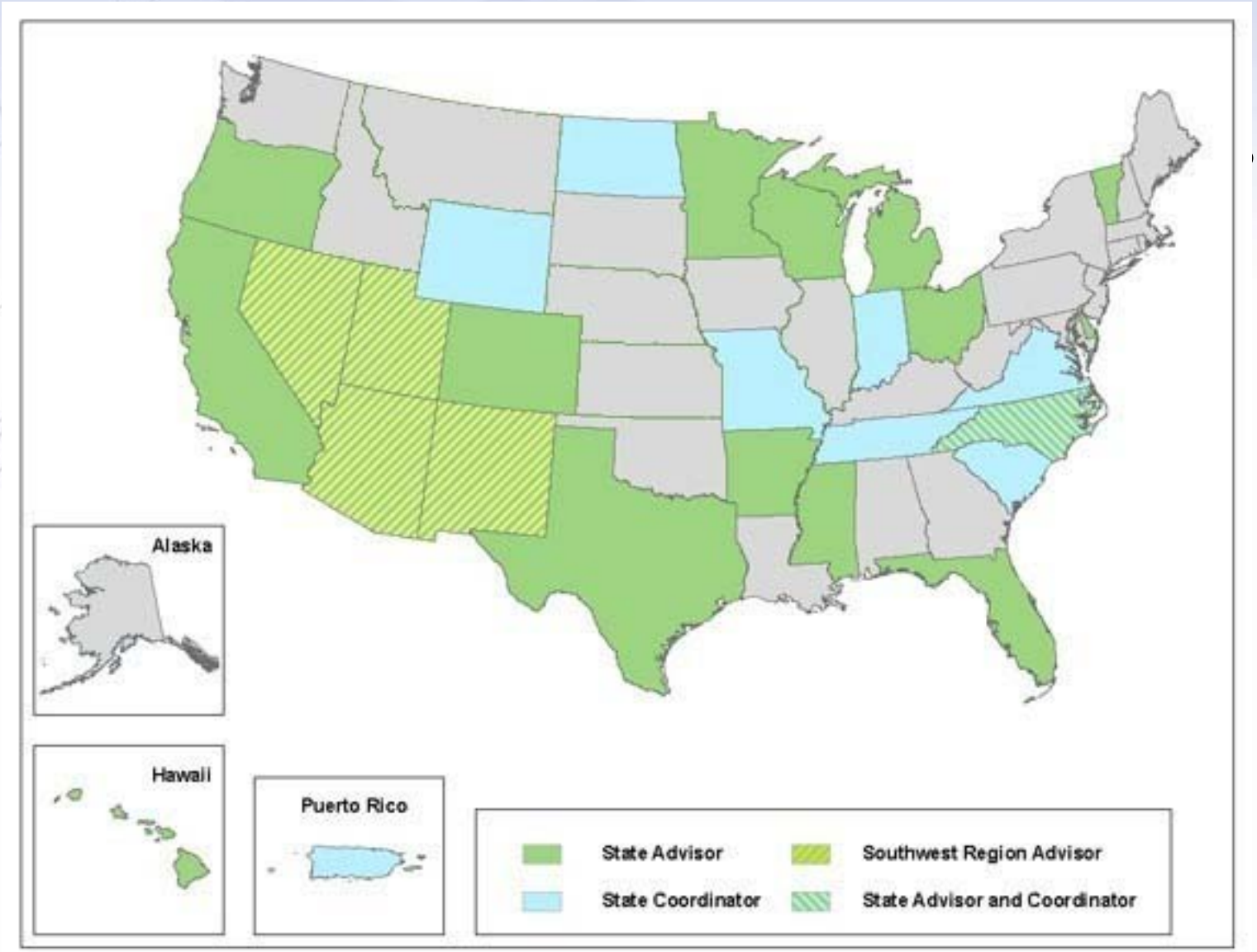
- NGS provides guidelines, training, and tools
  - Online webinars available from our web site ngs.noaa.gov [science and education]
  - Corbin Training Center

Where do I start?

- Tidal Datums Training (NGS, CO-OPS, NERRS)

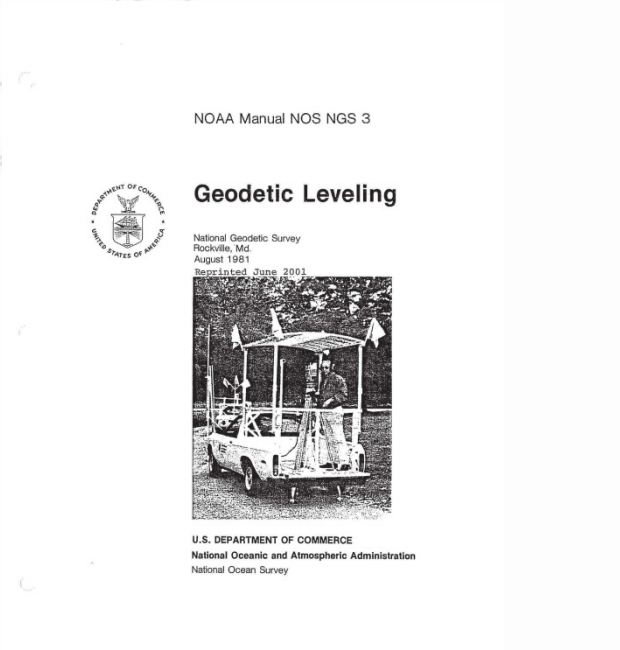


Where do I start?



Guidelines (examples)

- For experienced technicians / surveyors
  - High accuracy geodetic leveling
  - High accuracy GPS-derived positioning
  - Height Modernization

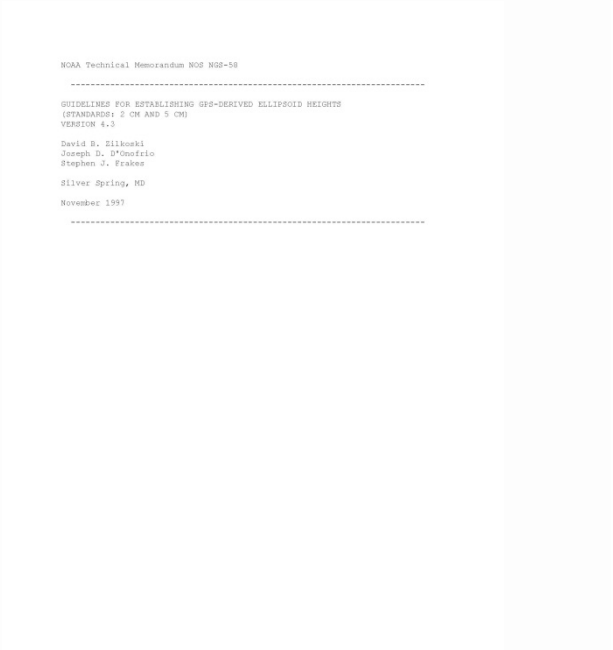


NOAA Manual NOS NGS 3

Geodetic Leveling

National Geodetic Survey
Rockville, Md.
August 1981
Reprinted June 2001

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Ocean Survey



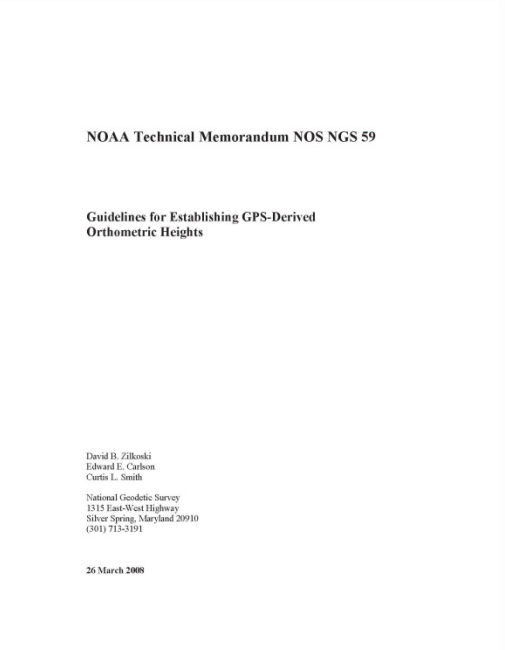
NOAA Technical Memorandum NOS NGS-58

GUIDELINES FOR ESTABLISHING GPS-DERIVED ELLIPSOID HEIGHTS
(STANDARDS: 2 CM AND 5 CM)
VERSION 4.3

David B. Zilkoski
Joseph D. D'Onofrio
Stephen J. Frakes

Silver Spring, MD

November 1997



NOAA Technical Memorandum NOS NGS 59

Guidelines for Establishing GPS-Derived Orthometric Heights

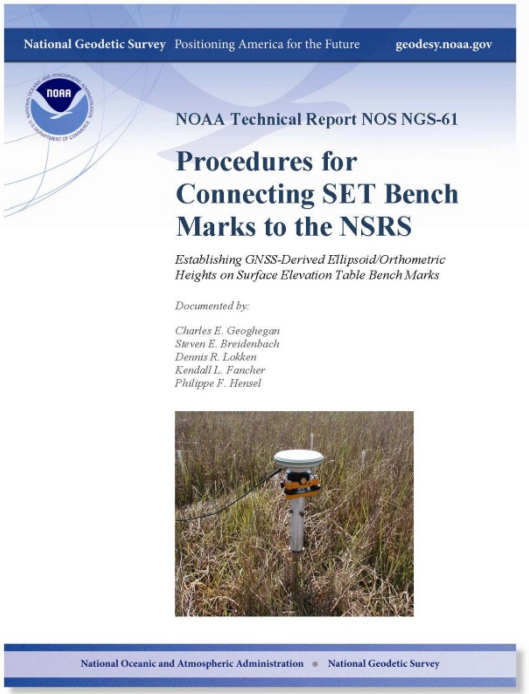
David B. Zilkoski
Edward E. Carlson
Curtis L. Smith

National Geodetic Survey
1315 East-West Highway
Silver Spring, Maryland 20910
(301) 713-3191

26 March 2008

Guidelines (examples)

- For technical professionals
  - Geospatial infrastructure for Sea Level Change Sentinel Sites
  - GPS-based heights on SETs
  - Tidal Datums Computations
  - SET guidelines



Ask a Surveyor!

- Florida: David Newcomer (david.newcomer@noaagov)
- Mississippi: Denis Riordan (denis.riordan@noaa.gov)
- Texas: Cliff Middleton (cliff.middleton@noaa.gov) & Daniel Prouty (dan.prouty@noaa.gov)

Questions?

NOAA's National Geodetic Survey Positioning America for the Future www.ngs.noaa.gov

TIDES & CURRENTS

Search

Home | Products | Programs | Partnerships | Education | Help

- Tides
- Great Lakes Water Level
- Currents
- Meteorological Observations
- Conductivity
- Bench Marks
- Storm QuickLook
- Datums
- Harmonic Constituents
- Operational Forecast System
- PORTS - Real Time Obs.
- Sea Level Trends
- Inundation Analysis
- Extreme Water Levels
- Astronomical Data
- nowCOAST
- Publications
- IOOS Data Portal
- Request Products
- HAB - Harmful Algal Blooms
- Google Earth/KML Files

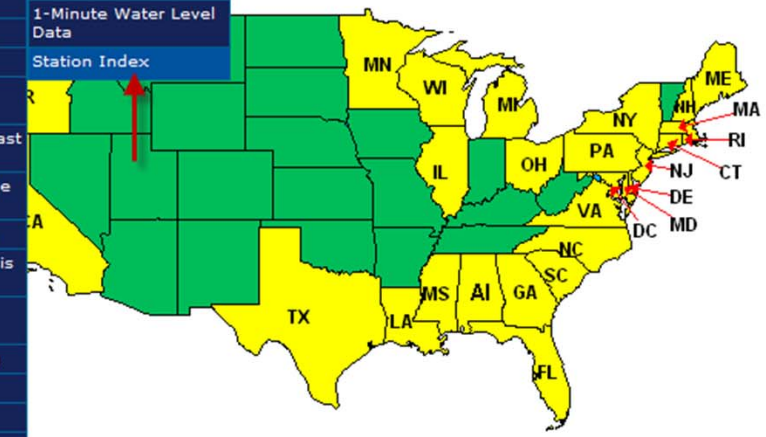
- Observed Data - Active Stations
- Historic Data
- NOAA Tide Predictions
- High/Low Tide Predictions
- "Tides Online"
- 1-Minute Water Level Data
- Station Index

Station Indices

All Stations
Maine
New Hampshire
Massachusettes
Rhode Island
Connecticut
New York
Pennsylvania
New Jersey
Delaware
Maryland
District of Columbia
Virginia
North Carolina
South Carolina
Georgia
Florida
Alabama
Mississippi
Louisiana
Texas
California
Oregon
Washington
Alaska
Hawaii
Atlantic Ocean
Eastern Pacific
Western Pacific

of Water Level Stations

est on the map or from pull down menu.
re for a complete list of stations.



Obtain CORS locations from CORS Map

www.ngs.noaa.gov/CORS/

Datasheet retrieval

(NGS Integrated Database)

http://www.ngs.noaa.gov/cgi-bin/datasheet.prl

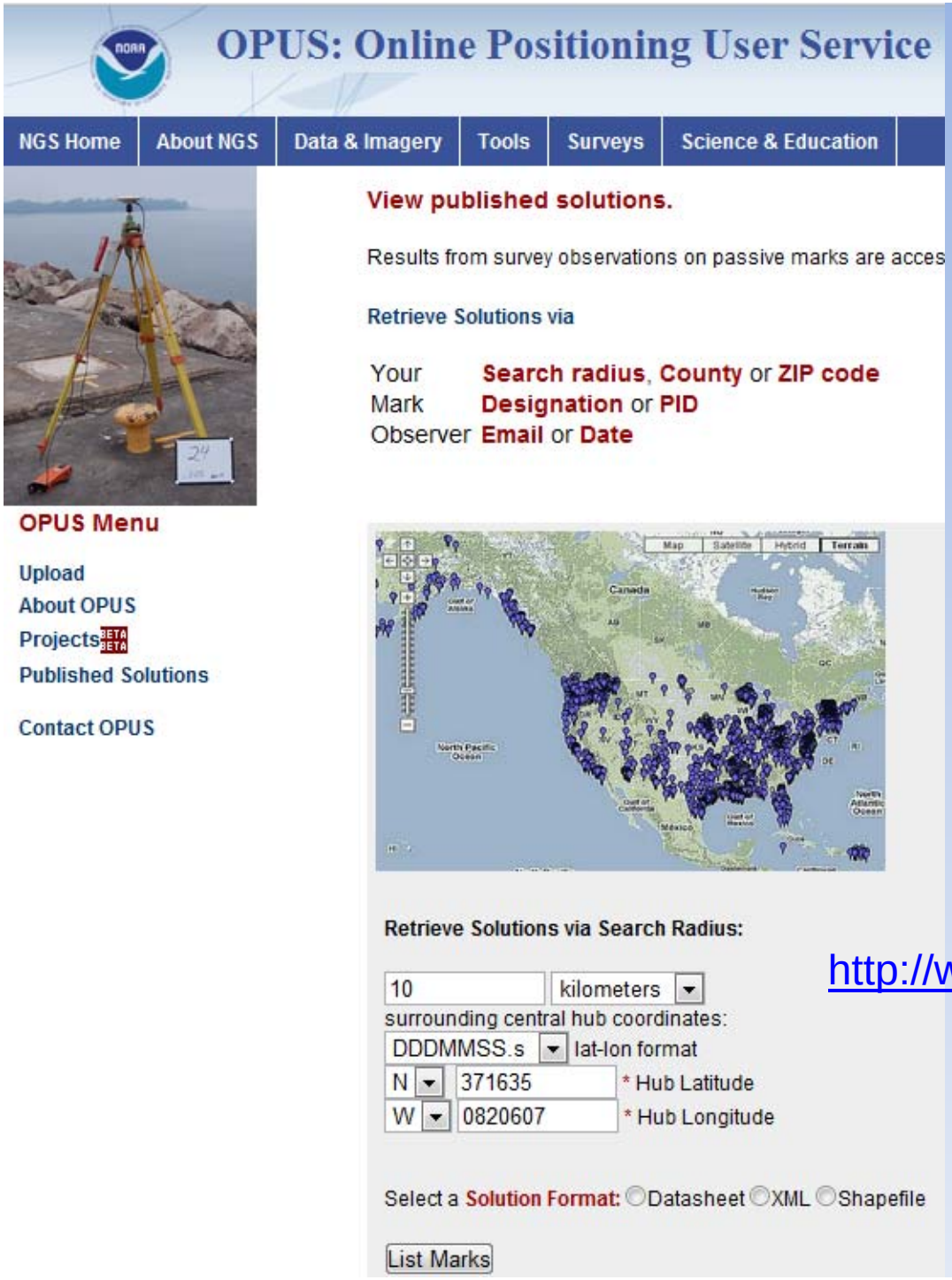
Data in the NGS IDB include both leveled heights and GSP derived positions.

The data have gone through a rigorous quality assurance and control process.

The NGS Data Sheet

```
See file  dsdata.txt for more information about the datasheet.
DATABASE =  ,PROGRAM = datasheet, VERSION = 7.61                              1
National Geodetic Survey,   Retrieval Date = AUGUST  4, 2008
 HV0907 ***********************************************************************
 HV0907  DESIGNATION -  N 36
 HV0907  PID         -  HV0907
 HV0907  STATE/COUNTY-  MD/ANNE ARUNDEL
 HV0907  USGS QUAD   -  BRISTOL (1979)
 HV0907
 HV0907                          *CURRENT SURVEY CONTROL
 HV0907
 HV0907* NAD 83(1986)-  38 48 24.      (N)     076 41 39.      (W)      SCALED
 HV0907* NAVD 88     -         19.053  (meters)        62.51   (feet)   ADJUSTED
 HV0907
 HV0907  GEOID HEIGHT-          -33.09  (meters)                         GEOID03
 HV0907  DYNAMIC HT  -           19.042 (meters)        62.47   (feet)   COMP
 HV0907  MODELED GRAV-      980,057.6   (mgal)                           NAVD 88
 HV0907
 HV0907  VERT ORDER  -  FIRST     CLASS I
 HV0907
 HV0907.The horizontal coordinates were scaled from a topographic map and have
 HV0907.an estimated accuracy of +/- 6 seconds.
 HV0907
 HV0907.The orthometric height was determined by differential leveling
 HV0907.and adjusted in June 1991.
 HV0907
```

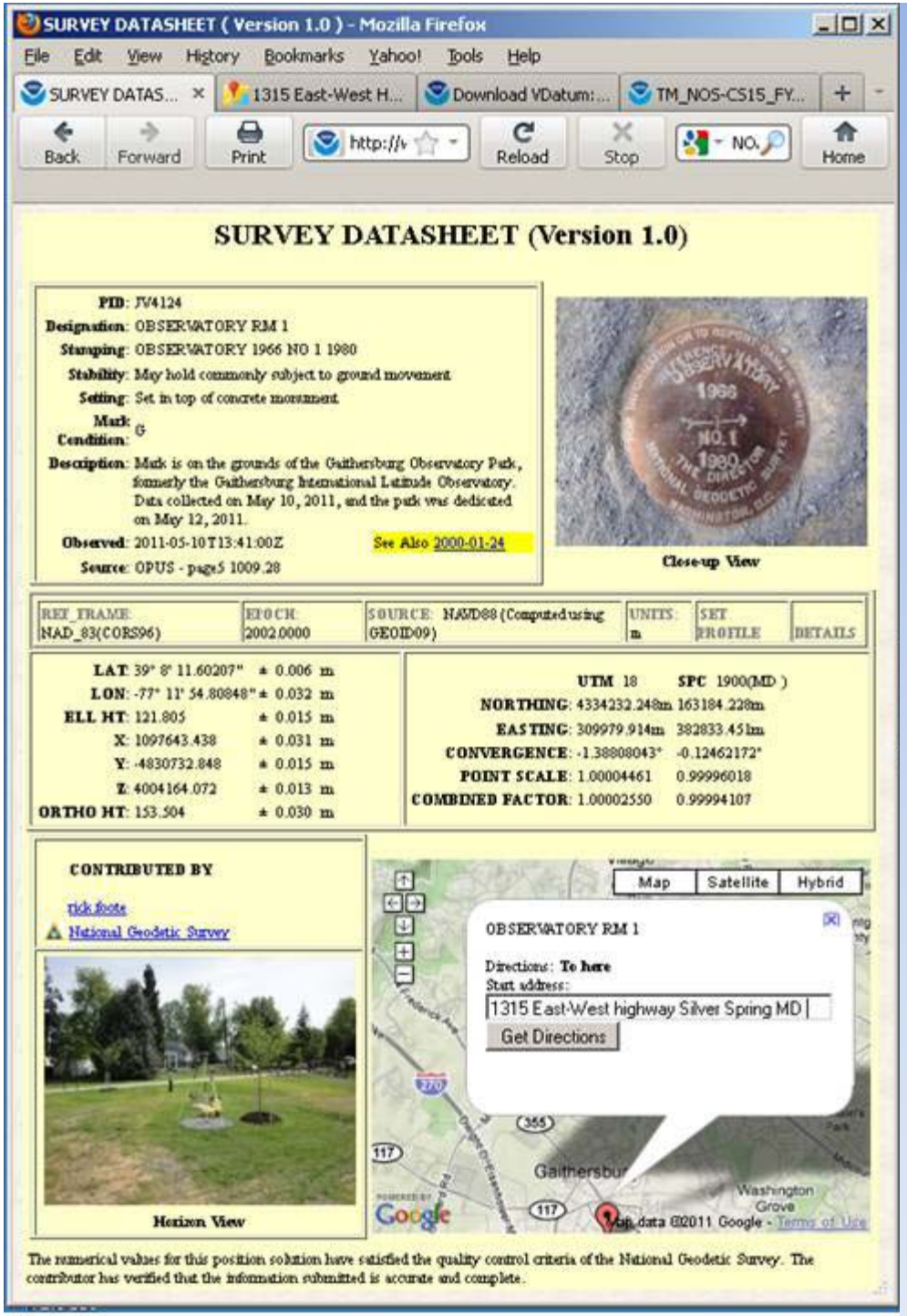
Note where to find orthometric height (NAVD88), and how it was obtained (via first order, class I leveling – the highest accuracy order/class)



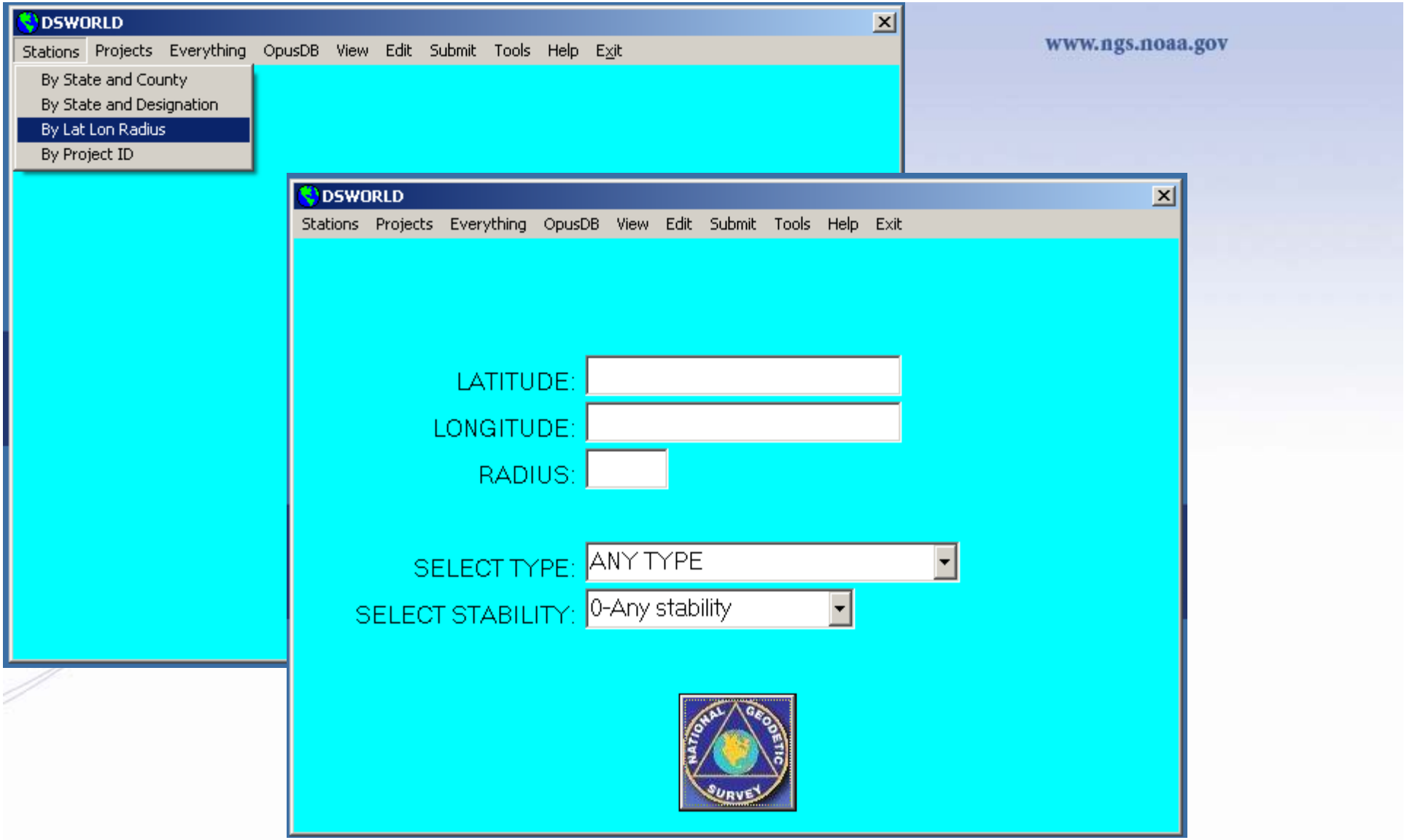
OPUS-DB Datasheet Retrieval

This allows you to retrieve published positional information that has been obtained via GPS

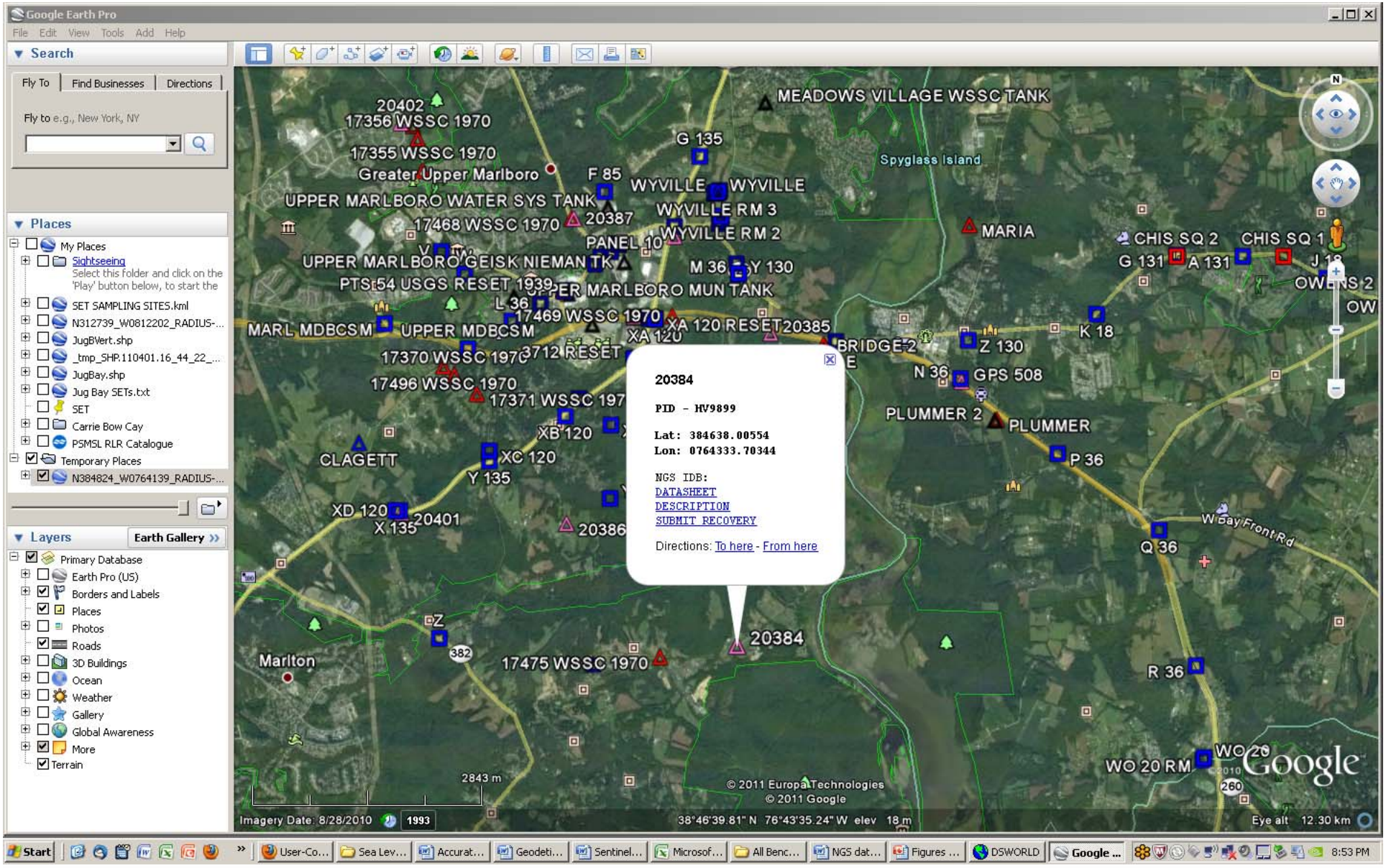
http://www.ngs.noaa.gov/OPUS/view.jsp



OPUS-DB Datasheet Retrieval



DSWORLD is a user-contributed software, available from NGS (http://www.ngs.noaa.gov/PC_PROD/PARTNERS/index.shtml) to retrieve data from both the NGS IDB and OPUS-DB. It can plot the data on Google Earth®



Marks will be plotted in Google Earth®, and by clicking on a mark, you will get a pop-up box with identifying information and the link to the datasheet