



# Accurately Assessing Sea Level Rise Impacts in Coastal Habitats

Adapting to Climate Change in the Mid-Atlantic

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Hyatt Regency Hotel, Cambridge Maryland

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# Questions

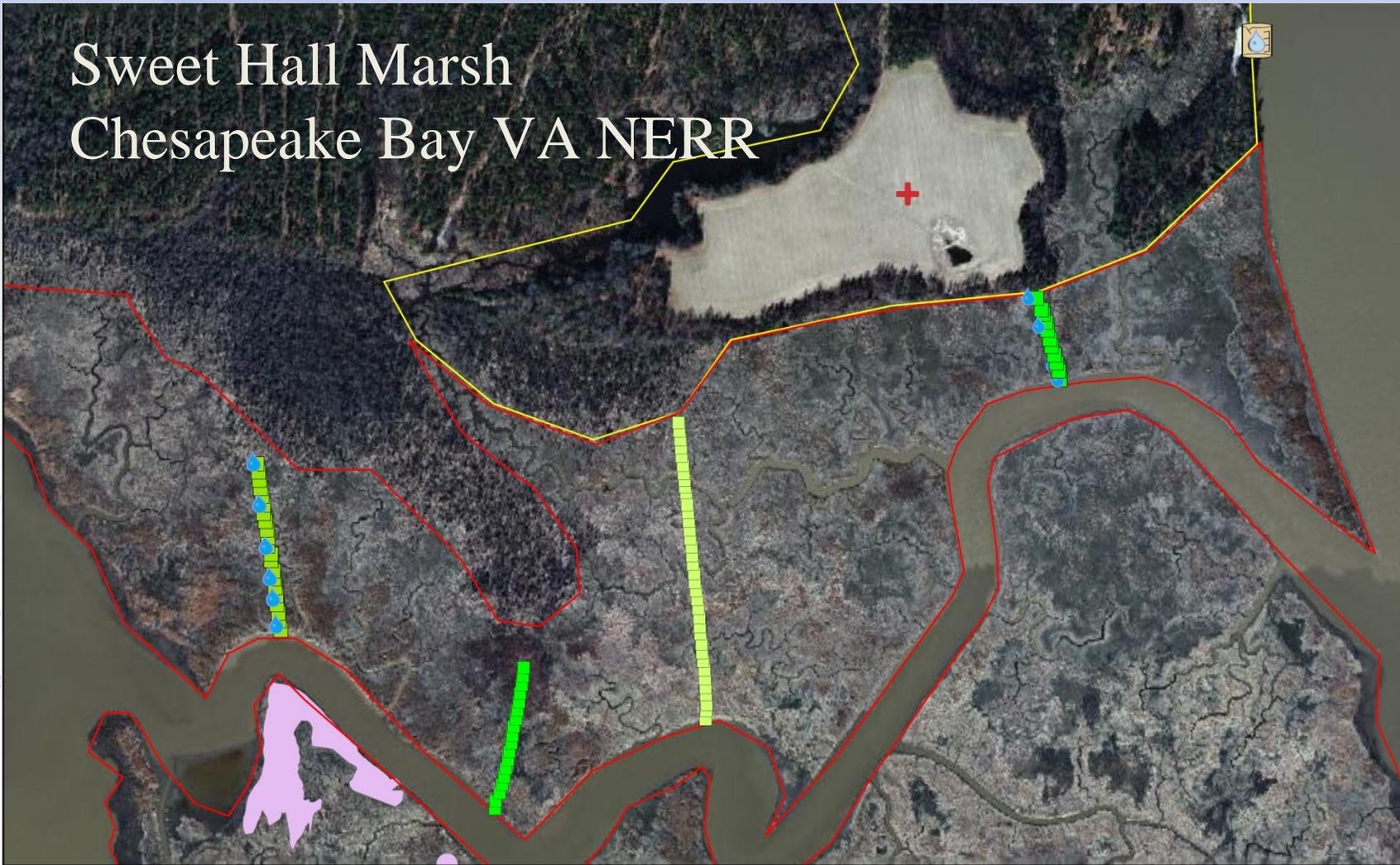
How can we measure sea level rise at the appropriate scale to accurately assess environmental change impacts?

How can we effectively combine spatially discrete ecosystem observations to assess the impacts of sea level rise on coastal marshes and compare results across a national network of Sentinel Sites?

# The Challenges

- Sea level rise/impact is locally expressed
- Different rates of motion among sea level, uplands, and coastal wetlands
- Multiple Datums – Multiple sensors each with own “zero point”
- Spatial scale – Millimeters of change per year over thousands of kilometers of shorelines
  - Local vs. Network Accuracy
- Time Scale – Need for ongoing observations for decades into the future.

# Sweet Hall Marsh Chesapeake Bay VA NERR



- Core Reserve Area
- Buffer for Core Reserve
- Weather Station
- Water Quality Station
- NERRS Phragmites Patches 2006

## Vegetation Transects 1 & 4

- Vegetation Plots
- Wells and SETs

- Vegetation Transect 2
- Vegetation Transect 3



# The Case for a Common Vertical Reference Frame

Observing systems such as tide stations, water level gages, and SETs require a “Zero Point” to compare to each other.

8571559 MCCREADYS CREEK, FISHING BAY MD  
8571892 CAMBRIDGE, CHOPTANK RIVER MD  
8576941 PARSONS CREEK MD

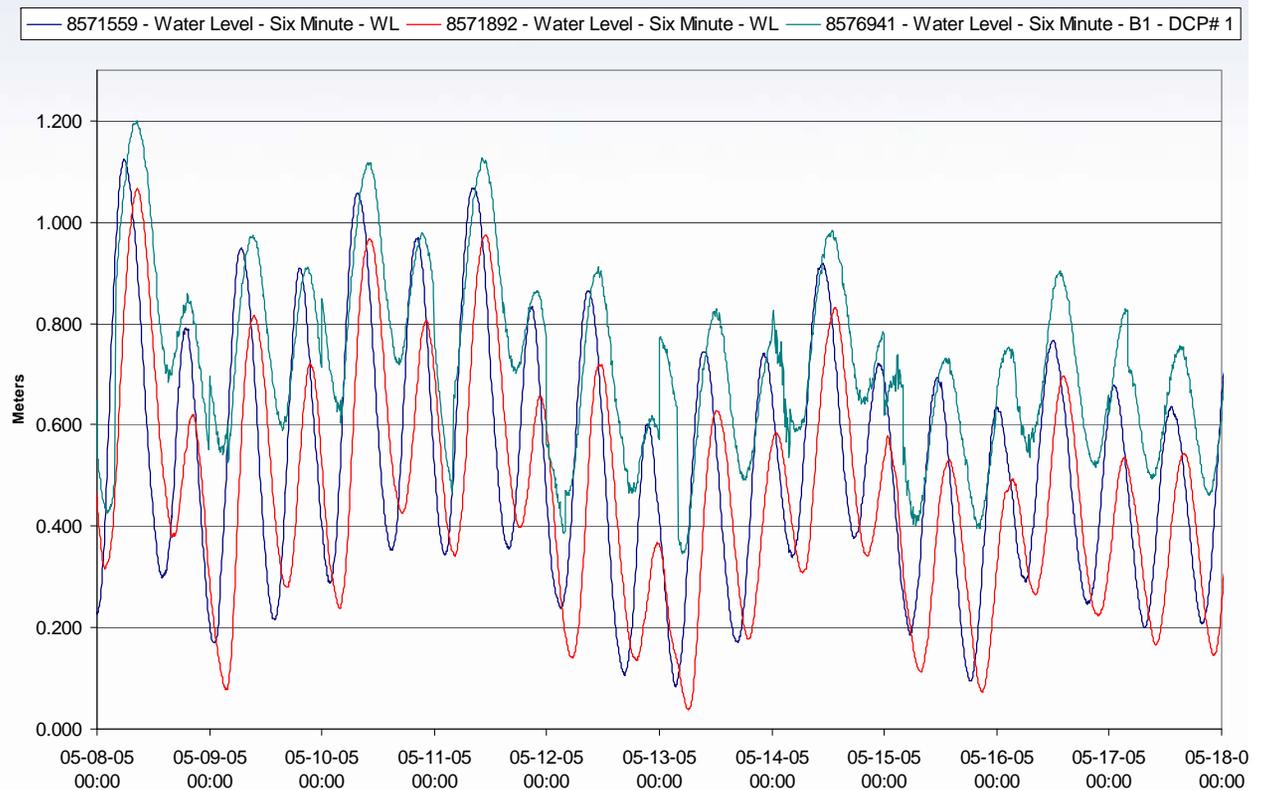


Each station referenced to its own local “island” datum

# The Case for a Common Vertical Reference Frame

8571559 MCCREADYS CREEK, FISHING BAY MD  
8571892 CAMBRIDGE, CHOPTANK RIVER MD  
8576941 PARSONS CREEK MD

NAVD88 or ITRF 2005, can serve as the common vertical reference system, providing the “Zero Point” to enable comparison of observations.



Each tide station referenced to a consistent vertical datum

# Three Height Systems

Datums are a set of fundamental elevations to which other elevations are referred.

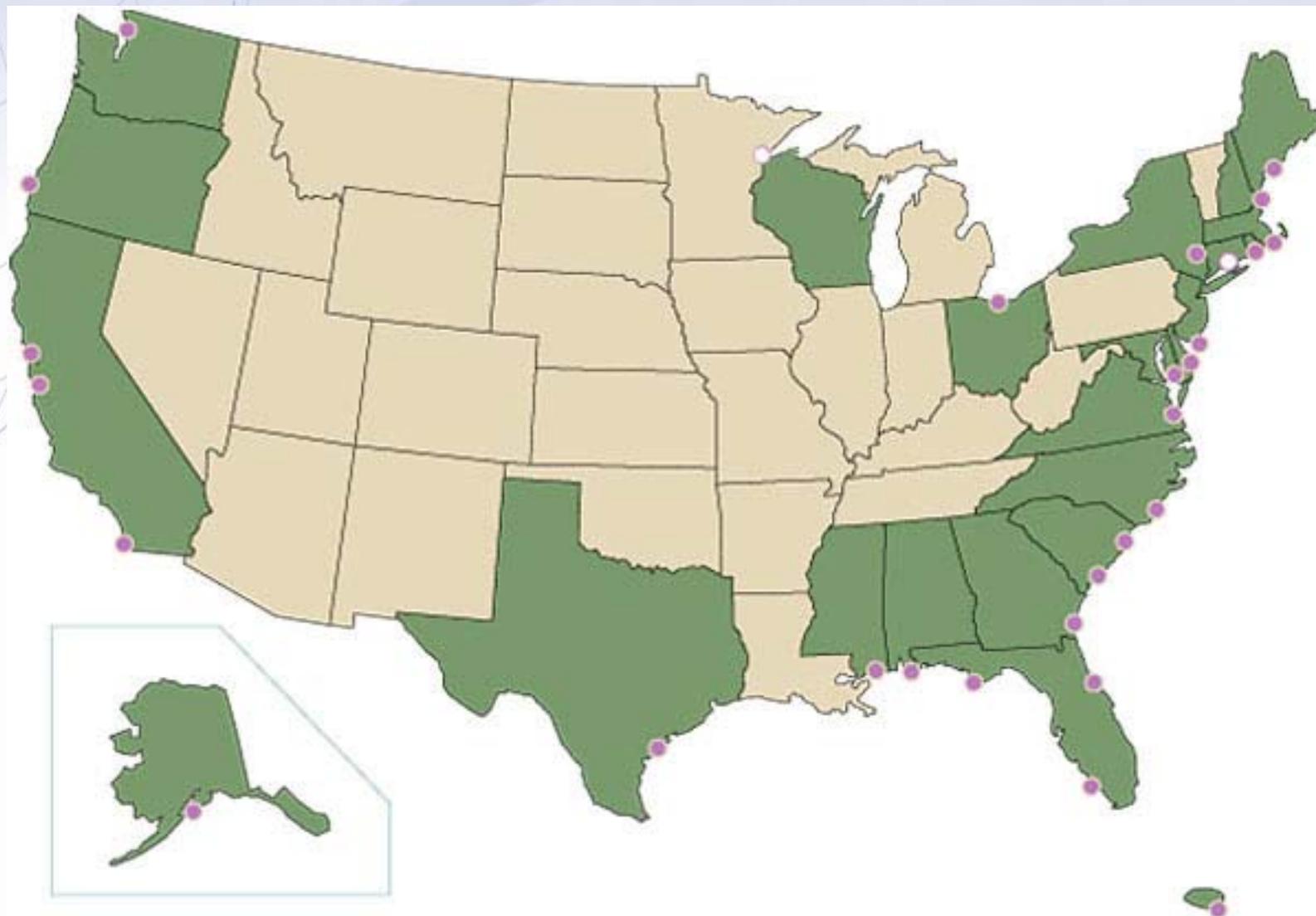


- Tidal Datums (*Tide Stations*)
  - Defined by observation of tidal variations over a specified epoch of time
    - Mean Lower Low Water (MLLW)
    - Mean Sea Level (MSL)
- Orthometric Datums (*Leveling*)
  - Related to the Geoid model of the Earth
  - Heights from differential leveling
    - North American Vertical Datum 1988 (NAVD 88)
- Ellipsoidal (3-D) Datums (*GPS*)
  - Related to an ellipsoidal model of the Earth
  - Heights directly from GPS
    - North American Datum 1983 (NAD 83)

# Four Components of Chesapeake Bay Virginia NERR



# National Estuarine Research Reserve System Network of 27 Reserves

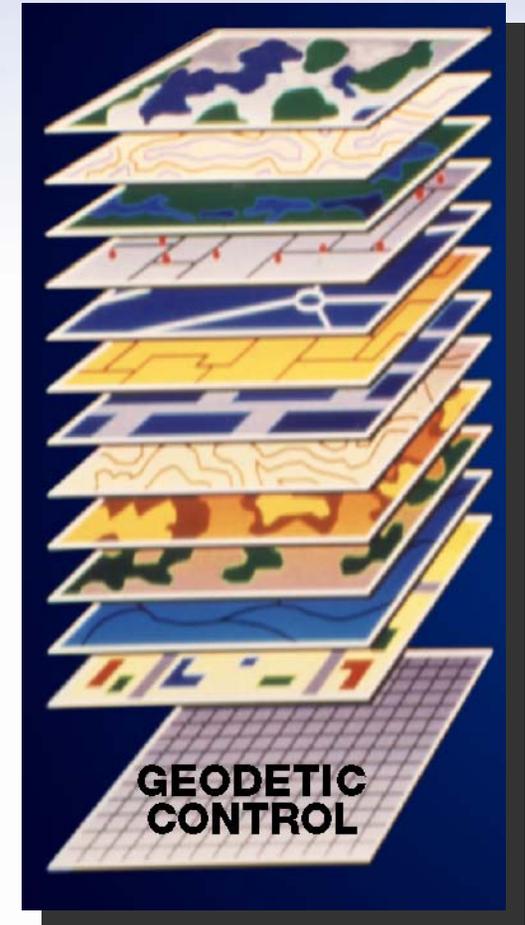


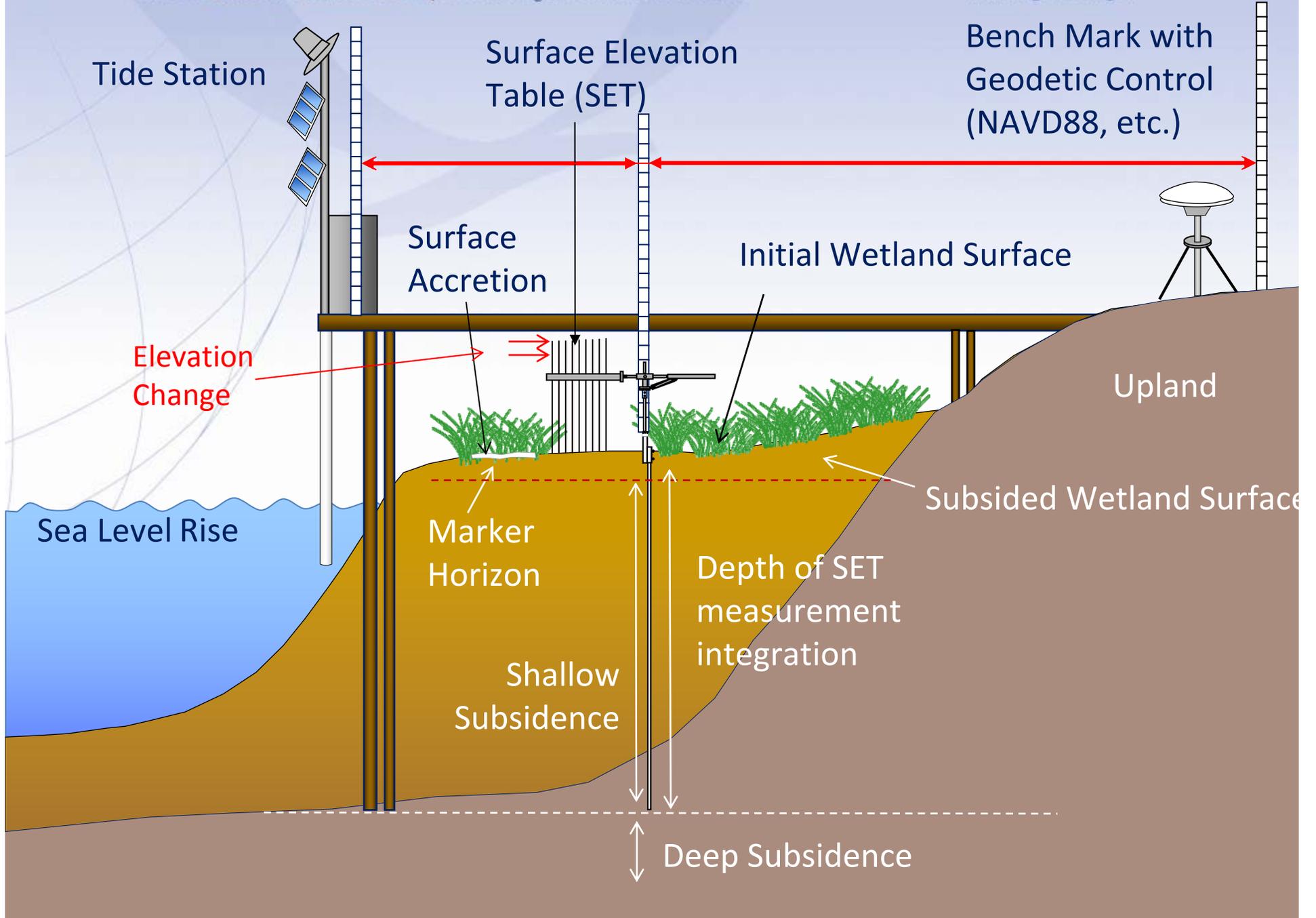
# National Spatial Reference System (NSRS)

## Consistent National Coordinate System

- Latitude
- Longitude
- Height
- Scale
- Gravity
- Orientation

and how these values *change with time*.





# Geospatial Infrastructure Components

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- Tide Stations (NWLON and temporary stations)
- Continuously Operating Reference Systems (CORS)
- Surface Elevation Table (SET) Networks

A network of permanent survey control points are required to accurately measure the relative movements of these observing systems and to compare their data trends over time.

These components provide the underlying geospatial foundation required to integrate other observations:

- Water Levels
- Vegetation Transects
- Marsh Elevation Models
- Multi-spectral imagery
- LiDAR topography
- Shallow Water Bathymetry

# NWLON

## National Water Level Observation Network (NWLON)

*A network of continuously operating tide stations that are the foundation for NOAA's tide prediction products*

The network provides:

- water level
- wind speed and direction
- barometric pressure
- air and water temperature
- conductivity/temp



# CORS Network

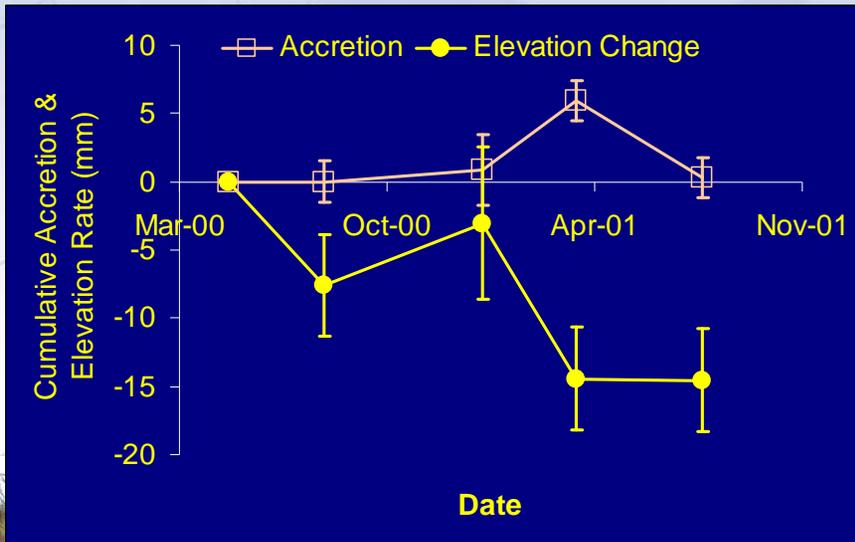


## Continuously Operating Reference Stations (CORS)

*A multi-purpose cooperative network providing 3-dimensional positioning*

- Will incorporate results from GRAV-D for increased accuracy of vertical positioning
- Co-locating with other instruments increases overall knowledge
- Built with partners in the public and private sectors, including state and local governments, universities, and private businesses

# SET Technology



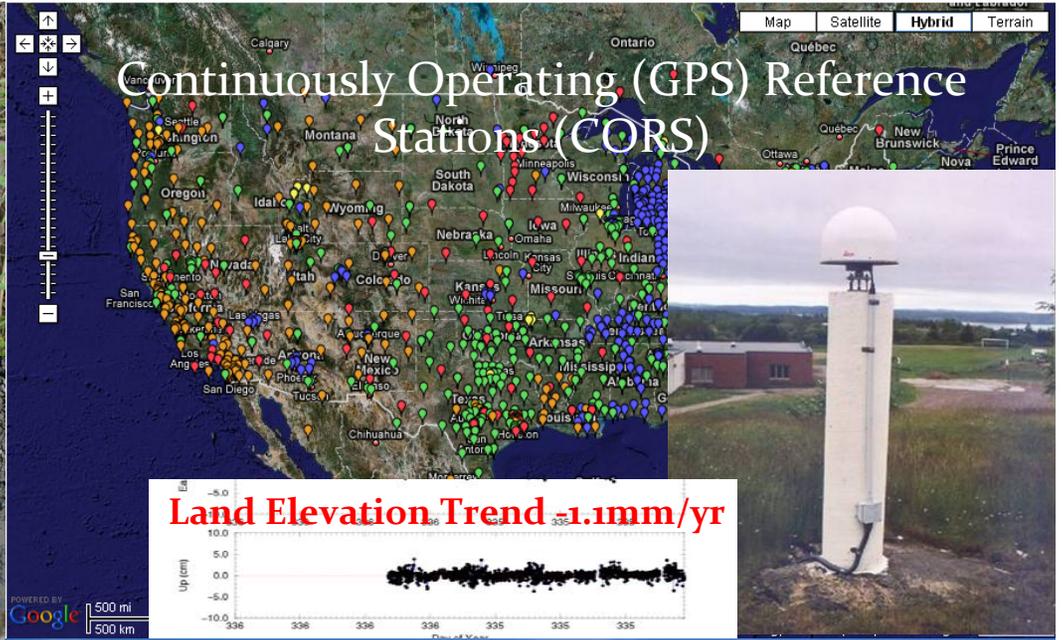
## Surface Elevation Tables (SETs)

*Portable leveling device to measure relative elevation of wetland sediments.*

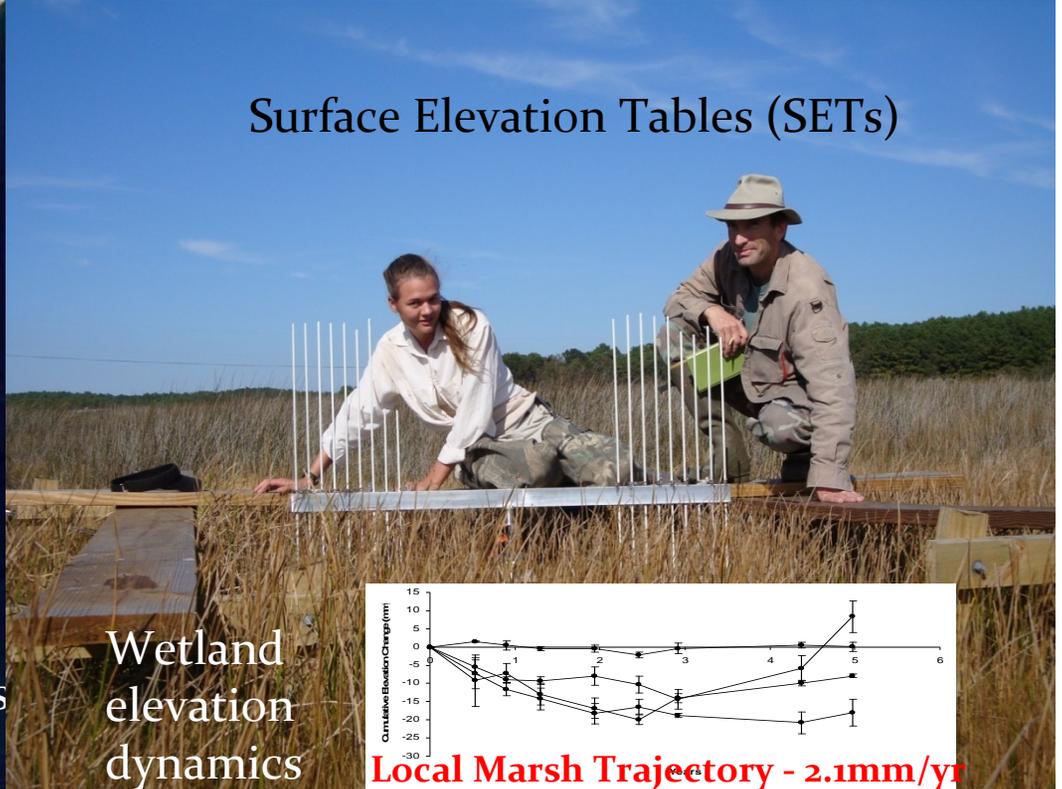
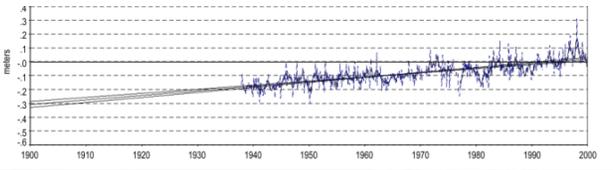
- SETs monitor coastal land elevation relative to local sea level rise
- Provides further understanding to processes leading to the formulation and maintenance of coastal elevation



## Survey Control Monuments



## Local Sea-Level Rise 3.29 mm/yr



# Surveying Methods for Establishing and Monitoring Vertical Control Networks

- **Static GNSS** – For Establishing control networks and monitoring stability of networks over time (subsidence)
  - 2 – 5 cm Accuracy (relative to NSRS)
  - Long occupation times (3 - 4 hours per point)
  - Relatively low technical expertise required
- **RTK GNSS** – For creating Digital Elevation Models and positioning remote or hard to reach points.
  - 1 to 5 cm accuracy (relative to local network)
  - Short occupation times (1 second to 6 minutes)
  - High technical expertise required
- **Leveling** – Highest accuracy method for local network connections and monitoring of network and sensor stability.
  - Sub-Centimeter accuracy (local and NSRS)
  - Time commitment depends on distance of connections
  - Moderate to High Technical expertise required

## Establishing a Local Geodetic Network at Each Reserve

### Tool: Static GPS

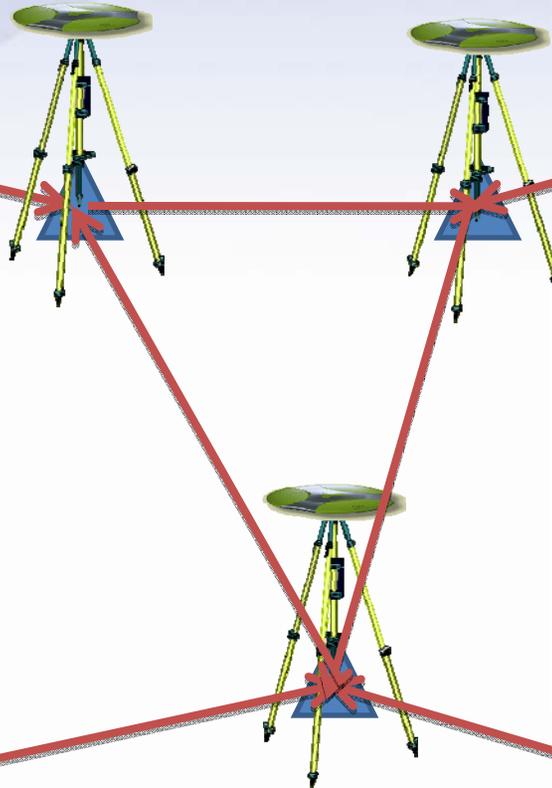
**Result: Sub-decimeter accuracy to the National CORS network.**



- Minimum of three geodetic control markers at each reserve or reserve component.

- Simultaneous observations of all 3 markers, during two separate GPS constellations.

- Observe for as long as practicable, 5 – 48 hour sessions recommended.



CORS

Control Monument

- Use OPUS to reduce GPS data and select option to “submit to database”.

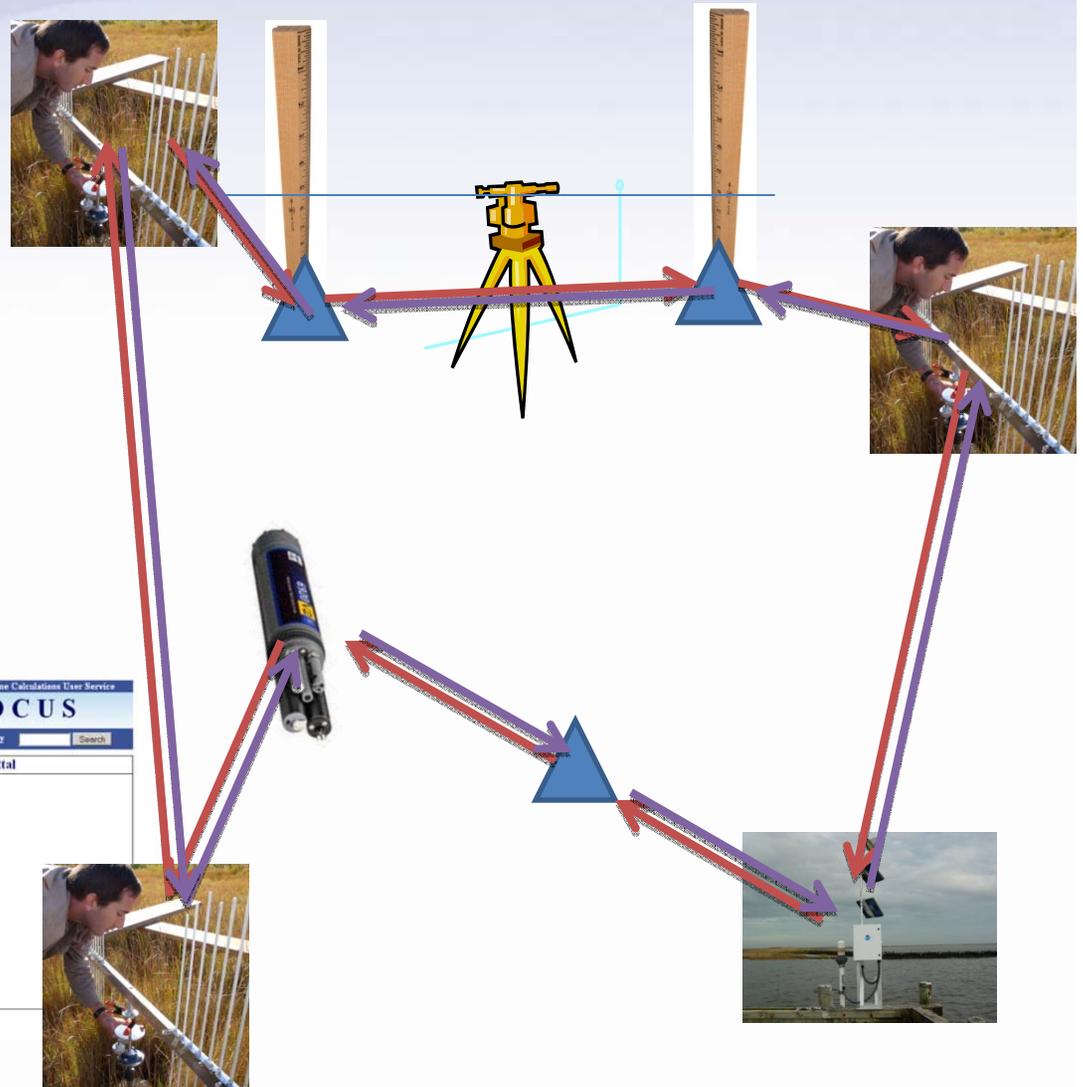
- Final positions are the average of the two independent solutions.



# Connecting NERRS sensors to the Local Geodetic Network Tool: Geodetic Leveling

Result: **Sub-Centimeter relative accuracy to the local network**

- Double run level loop (per NGS guidelines) through all Control Monuments, SWMP Station, or NWLON station if available, and as many SETs or other sensors as can be leveled to.
- Data are reduced using LOCUS tool.
- Averaged OPUS GPS Derived Heights held at one Control Monument.
- OPUS results from other monuments archived for future comparison.



Control Mon

SET

SWMP Sta

# Connecting SET sites and water level gauges to NAVD88

Digital (laser)  
barcode leveling

Second order  
class 1 leveling  
(6 mm km<sup>-1</sup>)



Reference: height modernized vertical marks (NGS or SET BM's)

# Connecting SET sites and water level gauges to NAVD88



NAVD88 height transferred to SET reference plane (deployed arm)

NAVD88 height transferred to pins of known lengths to sediment surface

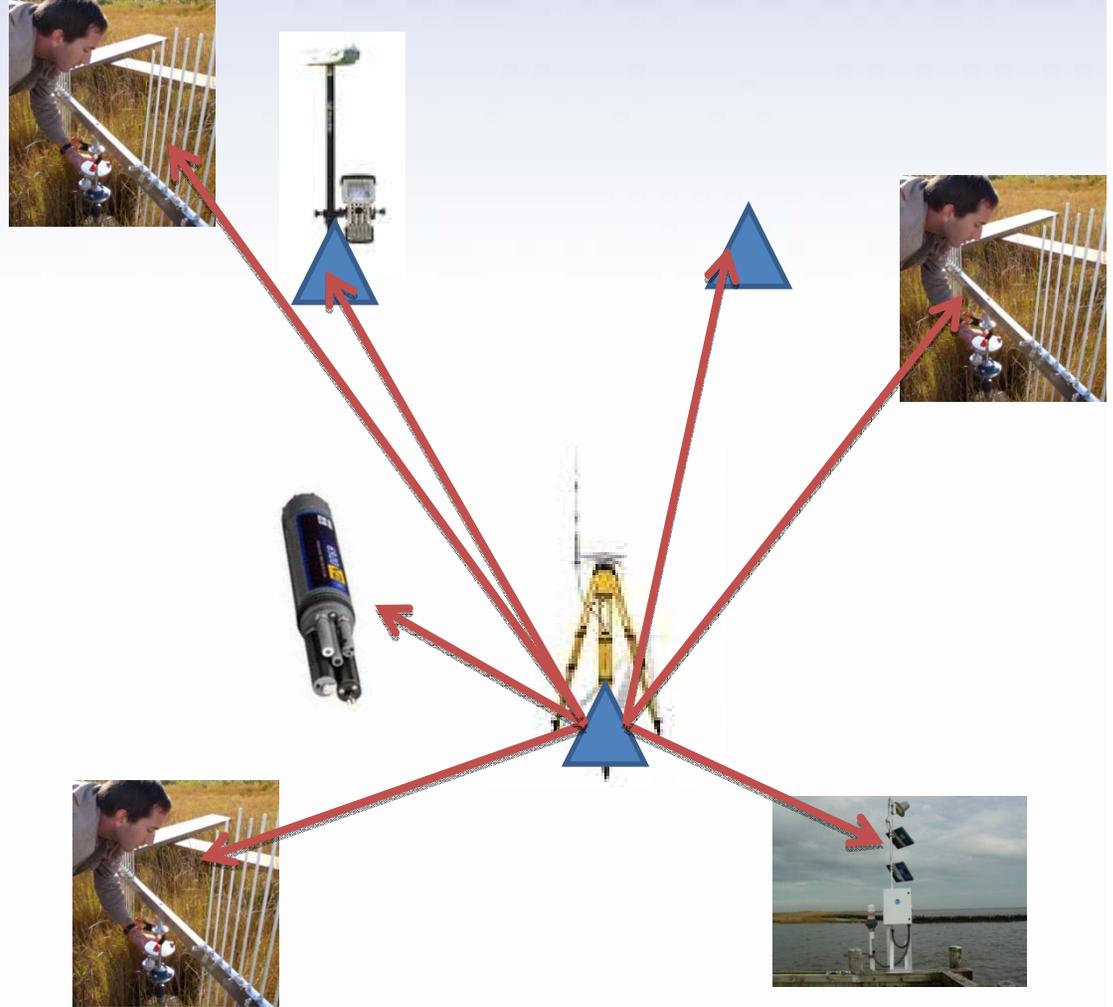
Photo courtesy of Don Cahoon, USGS

## Connecting NERRS sensors to the Local Geodetic Network Tool: Kinematic GPS

Result: **Centimeter level relative accuracy to the local network.**

- Following NGS RTK Guidelines, use RTK to determine position information for all sensors and other measurements not accessible by geodetic leveling.

- All RTK observations are conducted with the base station set up at one of the 3 local control marks.



Control Monument

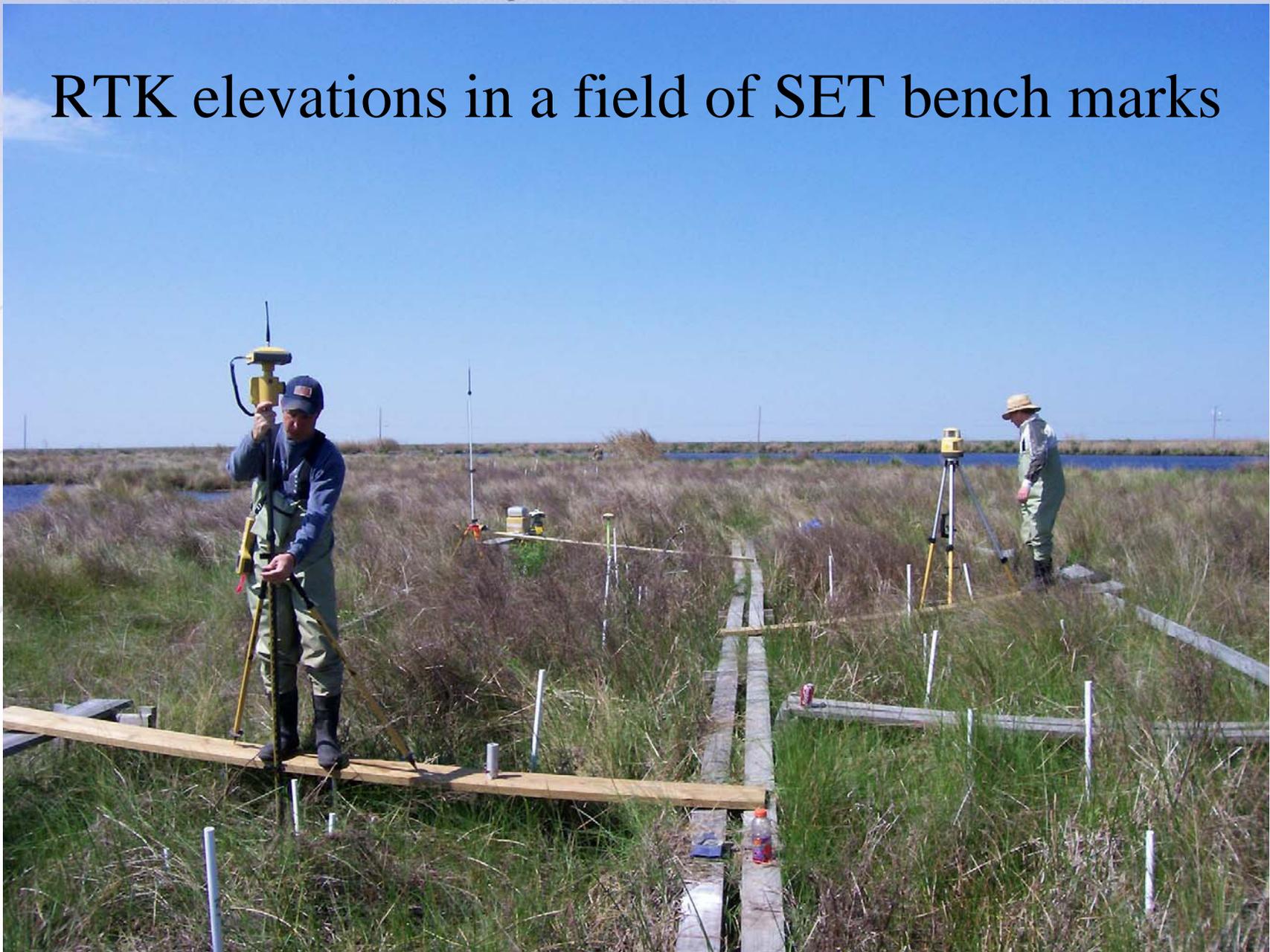


SET



Water level Station

# RTK elevations in a field of SET bench marks



# The Need for Ongoing Monitoring of Geospatial Infrastructure



# OPUS-DB: GPS Data Sharing

NGS Online Positioning Users Service (OPUS) – Processes static GNSS observations with nearby CORS data to provide accurate positions.

OPUS users will be provided, in addition to their standard position report, an option to **publish their position in the NGS database**

**SURVEY DATASHEET (Version 1.0)**

**ID:** EBBE01  
**Designation:** LARRIMORE 2006  
**Stamping:** Larrimore 2006  
**Stability:** May hold, commonly subject to ground movement.  
**Setting:** Object surrounded by mass of concrete.  
**Description:** This station is established to posthumously commemorate National Geodetic Survey Lead Computer Specialist CRAIG B. LARRIMORE for his success in promoting access and maintenance for the National Spatial Reference System. This mark demonstrates the initial use of the internet to automatically upload, process, adjust, archive, and display field survey data, made possible through Craig's efforts.  
**Note:** The station resides within a memorial garden on private property. Recovery is not recommended.  
**Observed:** 2006-01-12T15:59:00Z  
**Source:** OPUS - page 0612.06



**Close Up View**

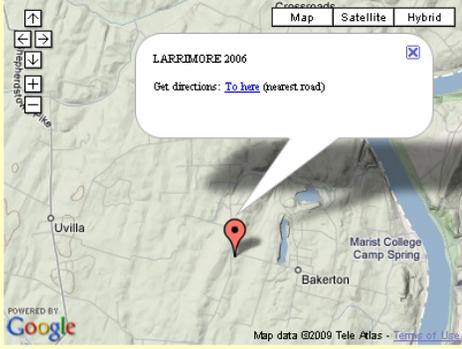
<b>REF_FRAME:</b> NAD_83(CORS96)	<b>EPOCH:</b> 2002.0000	<b>SOURCE:</b> [Geoid03 NAVD88]	<b>UNITS:</b> m	<b>SET PROFILE:</b>	<b>DETAILS:</b>
<b>LAT:</b> 39° 21' 51.77121" ± 0.004 m <b>LLN:</b> -77° 46' 21.55865" ± 0.019 m <b>ELL HT:</b> 98.939 ± 0.022 m <b>X:</b> 1045792.586 ± 0.021 m <b>Y:</b> -4825830.620 ± 0.014 m <b>Z:</b> 4023736.642 ± 0.016 m <b>ORTHO HT:</b> 132.598 ± 0.033 m		<b>UTM 18 SPC 4701(WVN)</b> <b>NORTHING:</b> 4360880.962m 97391.752m <b>EASTING:</b> 261128.806m 748846.707m <b>CONVERGENCE:</b> -1.75938732° 1.10165385° <b>POINT SCALE:</b> 1.00030260 0.99995111 <b>COMBINED FACTOR:</b> 1.00028707 0.99993559			

**CONTRIBUTED BY**

[krislwa.tadepalli](#)  
 National Geodetic Survey



**Horizontal View**



Map data ©2009 Tele Atlas - Terms of Use

The numerical values for this position solution have satisfied the quality control criteria of the National Geodetic Survey. The contributor has verified that the information submitted is acc

# Establishing Heights on Surface Elevation Tables (SET)

## Procedures for Connecting SET Bench Marks to the NSRS

Establishing GNSS-derived ellipsoid/orthometric heights on Surface Elevation Table Bench Marks

version 3-2  
01/2009

**Documented by:**  
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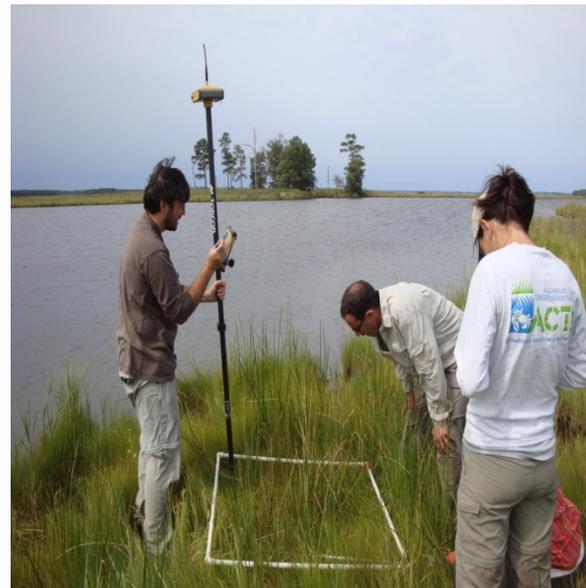
**DRAFT Document**  
Please submit comments to [Philippe Hensel](mailto:Philippe.Hensel@noaa.gov)

- *New* Fixed Dimension SET based on error analysis of previous instrument designs
- NGS Approved Guidelines for establishing Orthometric Heights on SET foundations
- Statistical framework for SET experimental design and data analysis
- Technical Assistance for SET deployment design and data analysis protocols

# Developing Surveying Protocols for Tying Sensors to Common Datums



NGS, CO-OPS and  
CBVANERR working on  
Guidelines Documents



# Conclusion

By concentrating geospatial infrastructure within and around biomonitoring stations and linking that infrastructure to a common reference frame through robust surveying methodology, we can **enhance capacity to assess change** and **increase our confidence** in our understanding of complex spatial relationships.

# Thank you

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# Thank You!

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# NOAA Resources

# NGS Corbin Training Center

[www.ngs.noaa.gov/corbin](http://www.ngs.noaa.gov/corbin)

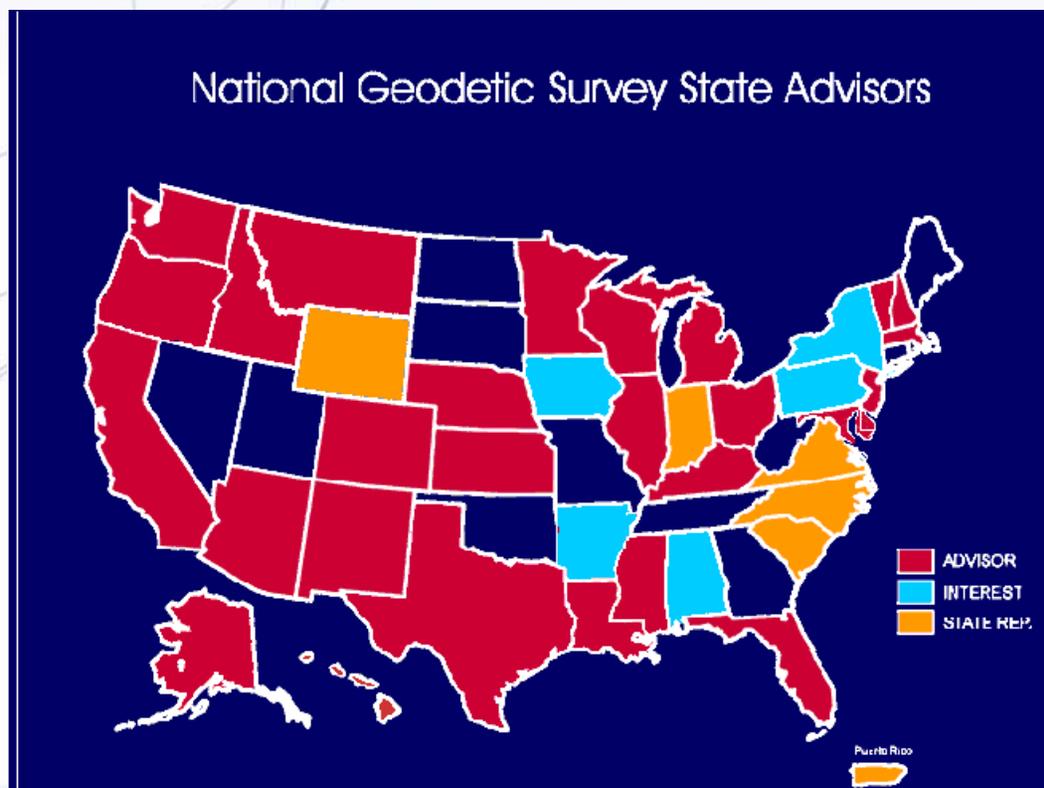
Your training resource for:

- Geodetic and Tidal Datums
- GPS (Static & RTK)
- Leveling
- Surface Elevation Tables



# NGS State Geodetic Advisors

[www.ngs.noaa.gov/ADVISORS](http://www.ngs.noaa.gov/ADVISORS)



Local, free technical support on datums and coordinates, and all your high accuracy surveying questions.



# GRAV-D:

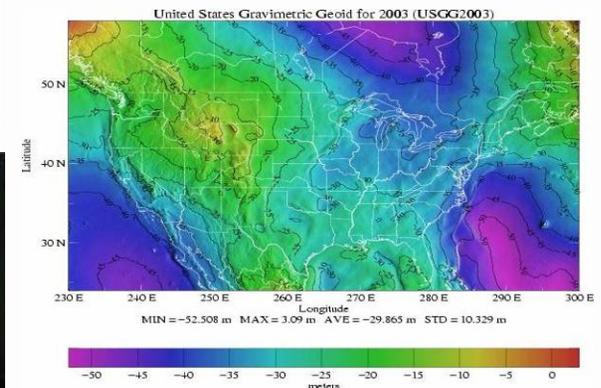
## Gravity for the Redefinition of the American Vertical Datum

Nationwide airborne gravity collection essential for the definition of an improved national vertical reference system

Profound implications for GPS elevation accuracy:  
*national elevations with GPS to ~ 2cm compared to as much as 2 meters today*



Aerial Gravity Collection for a new national vertical datum



# Integrated Ocean and Coastal Mapping (IOCM): Map Once, Use Many Times

- International Working Group on Ocean and Coastal Mapping (IWG-OCM)
- Coordination of ocean and coastal mapping data and activities
- Partnerships for resource synergies
- Integrated products and services

The screenshot shows the NOAA Coastal Services Center's Digital Coast website. The header includes the NOAA logo and the text "DIGITAL COAST". Below the header is a navigation menu with links for "Home", "Data", "Tools", "Training", and "In Action". The main content area is divided into several sections: "Data" (Learn more about the kinds of data available and download data.), "Tools" (Use these tools to turn data into useful information your organization needs.), "Training" (Update your skills by participating in one of these training programs.), and "Digital Coast In Action" (See how data and tools are used to address coastal management issues.). There is also a section titled "About the Digital Coast" which describes the network of diverse partners working together to address coastal issues. A sidebar on the right contains a "Digital Coast Website" section with a brief description of the site's purpose. The footer includes the NOAA Coastal Services Center logo and the text "United States Department of Commerce National Oceanic and Atmospheric Administration National Ocean Service". There are also links for "Contact Us", "Privacy Policy", "Link Disclaimer", and "USA.gov".

**Goal: Increase efficiency and improve coordination of many Federal mapping agencies.**



## Integration of LiDAR with Surface Elevation Tables (SETs)

