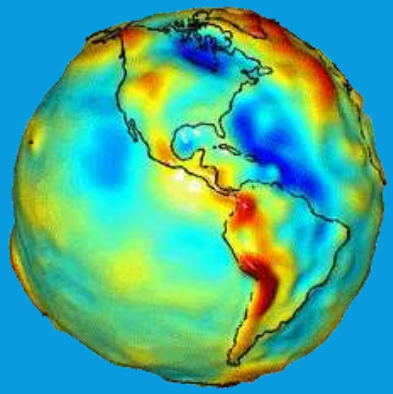


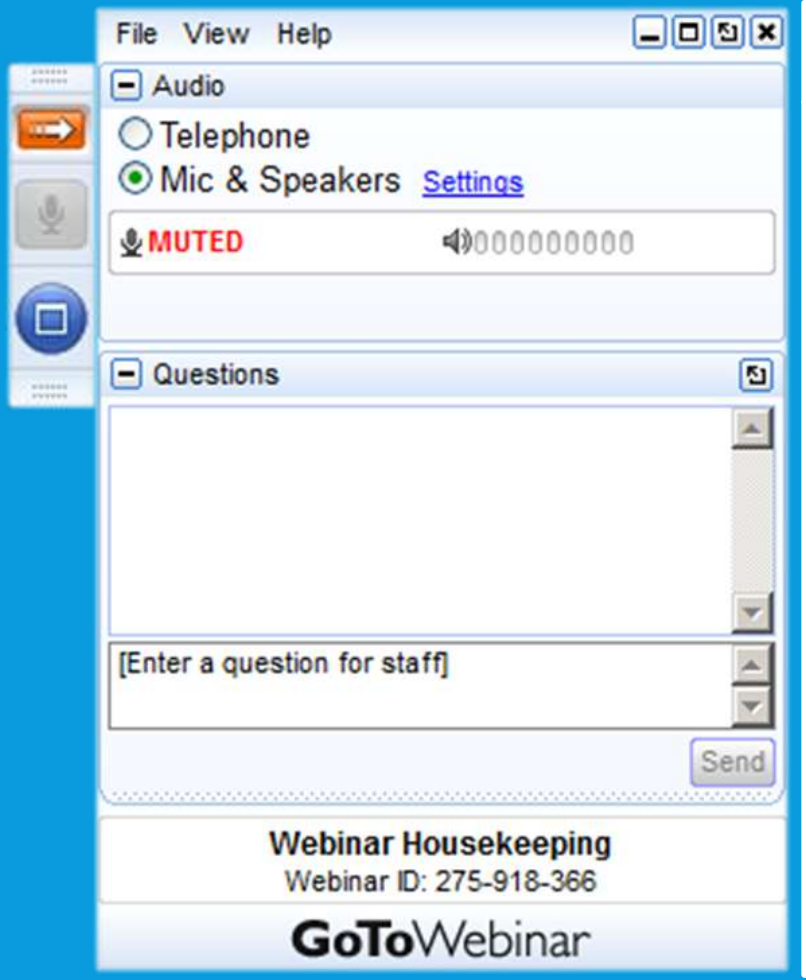
COOPERATING TECHNICAL PARTNER INFORMATION EXCHANGE

Vertical Datums: how they impact modeling & mapping

March 29, 2017

Association of State Floodplain Managers

AUDIO AND WEB SETTINGS



Your Participation

Open and hide your control panel using the red arrow button

Join audio:

- Choose “Mic & Speakers” to use VoIP
- Choose “Telephone” and dial using the information provided

*Submit questions and comments via the **Questions** panel*

WEBINAR LOGISTICS

- All lines will be automatically be muted.
- ***Use the Question window in your webinar control panel to submit your question or comment to the ASFPM Organizer.***
- Select questions will be read to the presenter and answered.
- Questions not asked during the webinar will be answered and made available in a follow-up email.

CONTINUING EDUCATION CREDIT (CEC) LOGISTICS

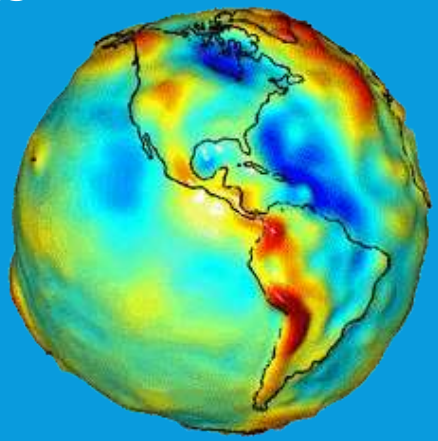
- Certified Floodplain Managers (CFM®) are eligible for 1 Continuing Education Credit (CEC) for participating in this webinar.
- You must register individually and indicate you are a CFM® at time of registration.
- Eligibility for CEC is dependent on your participation in poll questions and time spent viewing the webinar, as determined by the webinar software.
- ***Attending this webinar in a group setting or only viewing the recording is NOT eligible for CEC.***

AGENDA

- Introduction - Alan Lulloff

Vertical Datums: how they impact modeling & mapping **presented by Doug Marcy & Brandon Krumwiede, NOAA Office for Coastal Management**

  - Definition and overview of vertical datums
  - History of previous datums
  - Transformations
  - NOAA VDATUM
  - Upcoming GRAV-D



- Questions/Discussion

ASFPM MAPPING AND ENGINEERING STANDARDS COMMITTEE
COOPERATING TECHNICAL PARTNER SUB-COMMITTEE

Co-chairs:

- Amanda Flegel, PE, CFM; Illinois State Water Survey
- Thuy Patton, PE, CFM; Colorado Water Conservation Board

Goals:

- ***Identify common concerns***
- ***Provide opportunities for information exchange***
- ***Identify training needs***
- ***Promote and document the value of CTPs***

Integrating Elevation Data

Why Integrate Elevation Data?

- Driving factor is being able to map and model across the land-water interface. Multiple datasets can be used for this, including topographic and bathymetric data.

- Elevation data are used for a number of applications:
  - Marine navigations
  - Shoreline delineation
  - Coastal habitat restoration
  - Erosion monitoring
  - Storm surge modeling
  - Tsunami modeling

- Multiple data sets are often used, in which case data consistency (i.e., the spatial reference) is essential for maintaining data accuracy

Integrating Elevation Data

Integrating Elevation Data: Things to Consider

- Spatial Framework
  - Coordinate system: projection, datum, ellipsoid
  - Vertical datum used to reference height and depth values

- Resolution
  - Cell size that will be used to represent elevation data
  - Scale of application/analysis
  - Topographic data are usually available at a higher resolution than bathymetric data

- Purpose
  - What do you intend to do with the results?
  - What are your accuracy requirements?

- Processing the data
  - Converting data into a consistent format
  - What tools are available to help you do this?

Coastal Inundation Mapping – Training

http://coast.noaa.gov/digitalcoast/training/inundationmap

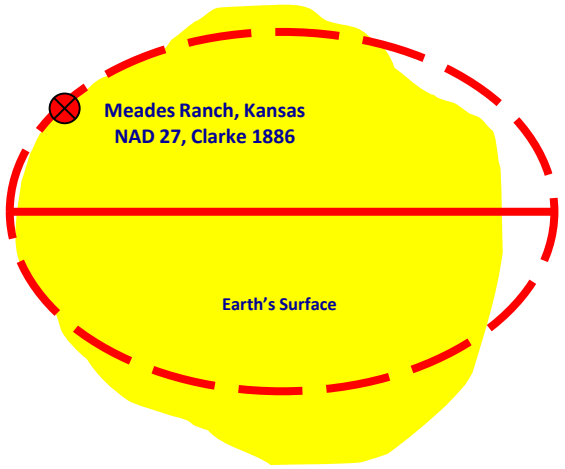
Mapping Fundamentals

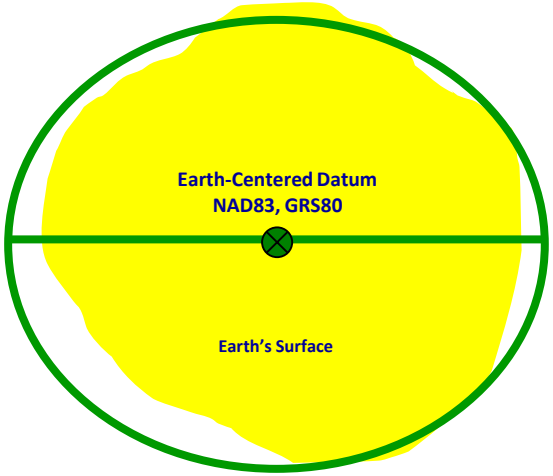
Datums

- A datum serves as a reference point for calculating surface locations, heights, and depths

- A datum can be geocentric (Earth-centered) or locally established

- Types of Datums:
  - **Horizontal datum**: defines the position of the ellipsoid relative to the Earth, and is used for measuring X,Y locations on the Earth's surface
  - **Vertical datum**: references a modeled surface for calculating height or depth at a particular location on the Earth's surface.

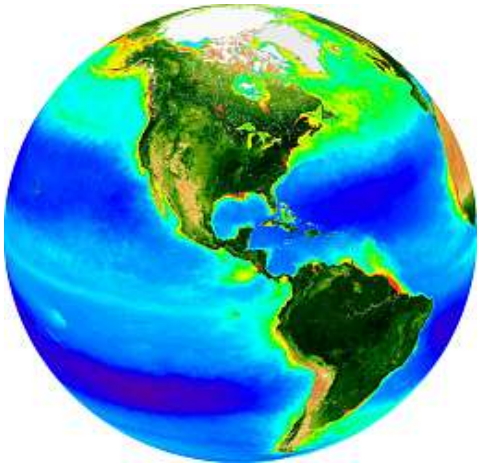




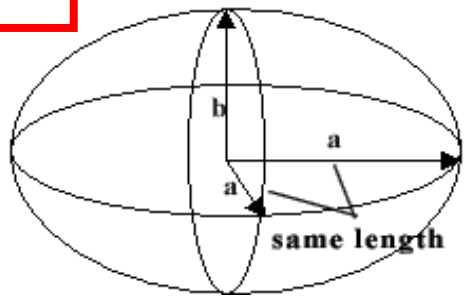
Mapping Fundamentals

Ellipsoids

- Many datums (both vertical and horizontal) are based on ellipsoids
- An ellipsoid is a three-dimensional mathematical model of the Earth's shape
- Simplified representation of earth (smooth surface) to make it easier to measure distances and calculate locations
- Ellipsoids used in the United States:
  - Clark 1886
  - Geodetic Reference System of 1980 (GRS 80)
  - World Geodetic System of 1984 (WGS 84)



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



Mapping Fundamentals

Horizontal Datums

- North American Datum of 1927 (NAD 27): based on Clarke 1866 ellipsoid
- North American Datum of 1983 (NAD 83): based on the GRS80 ellipsoid; the official datum for the U.S.
- World Geodetic System of 1984 (WGS 84): based on the WGS84 ellipsoid

Horizontal Datums Commonly Used in the U.S.

Ellipsoid	Semi-Major Axis (m)	Semi-minor Axis (m)
Clarke 1866	6378206.4	6356583.8
GRS80 (1980)	6378137	6356752.31414
WGS84 (1984)	6378137	6356752.3142451 8

Mapping Fundamentals

Vertical Datums

- A vertical datum is an established surface that serves as a reference to measure or model heights and depths.
- *All* elevation data are referenced to a vertical datum.
- Vertical datums are derived using one of three models:
  - **Ellipsoidal (geometric) Models**: A simplified surface that represents the Earth's shape and size
  - **Orthometric (physical) Models**: A physical and gravimetric model that approximates mean sea level (MSL)
  - **Tidal Models**: A datum that references water levels according to a certain tidal stage
- To create a continuous grid of elevation surfaces, the data sets must reference the same datum so that the height and depth values are consistent.

Mapping Fundamentals

Vertical Datums

Commonly Used Vertical Datums in the U.S.

Datum	Model Type	Examples
North American Vertical Datum of 1988 (NAVD 88)	Orthometric	USGS NED Digital Elevation Models
National Geodetic Vertical Datum of 1929 (NGVD 29)	Orthometric	Older FEMA Flood Maps
Mean Lower Low Water (MLLW)	Tidal	Hydrographic Surveys
Mean High Water (MHW)	Tidal	Shoreline Data
WGS84, NAD83	Ellipsoidal	LIDAR-derived topographic data

Mapping Fundamentals

Ellipsoidal Datums

- Remember that an ellipsoid is a simplified representation of the Earth's shape and size
- Primary means of horizontal reference, but can also be used as a vertical reference
- LiDAR is an example of data that is collected using an ellipsoid datum for referencing height values
- Height is the distance between a point on the Earth's surface to the ellipsoid
- Referred to as height above the ellipsoid, or as the geodetic height

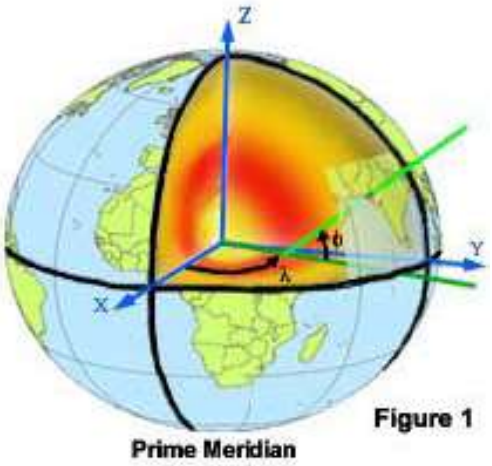


Figure 1

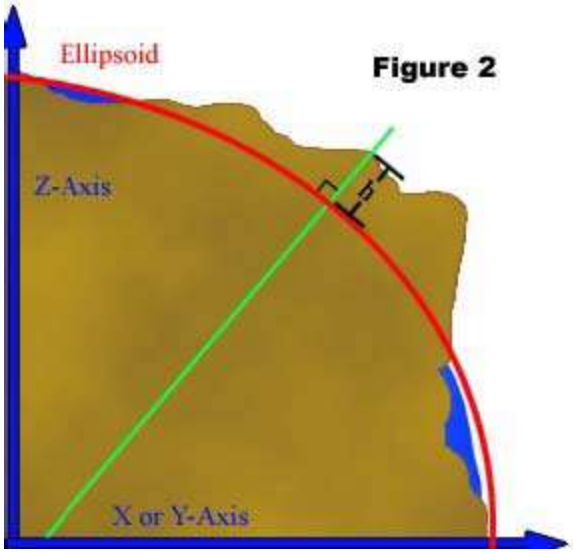
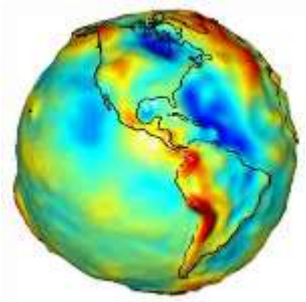


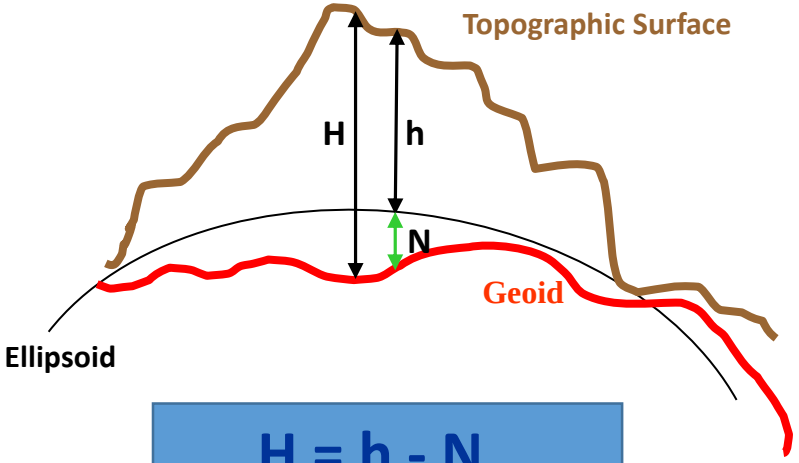
Figure 2

Mapping Fundamentals

Orthometric Datums

- A geoid is “the equipotential (level) surface of the Earth’s gravity field that, on average, coincides with mean sea level in the open undisturbed ocean” *(NDEP, Guidelines for Digital Elevation Data).*
- Most current geoid used for deriving NAVD88 Geoid Models: 12b, 12a, 09, 06, 03, 99, 96, 93, 90
- When geoid is updated, NAVD88 has been updated
- The geoid height can be above or below the ellipsoid, therefore can be either positive or negative value.
- The orthometric height is the elevation above the geoid





H = h - N

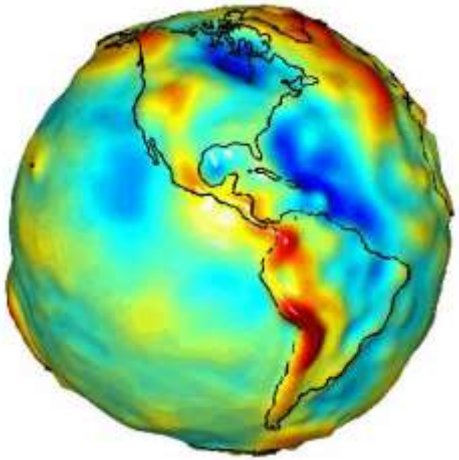
H = Orthometric Height

h = Ellipsoidal Height

N = Geoid Height

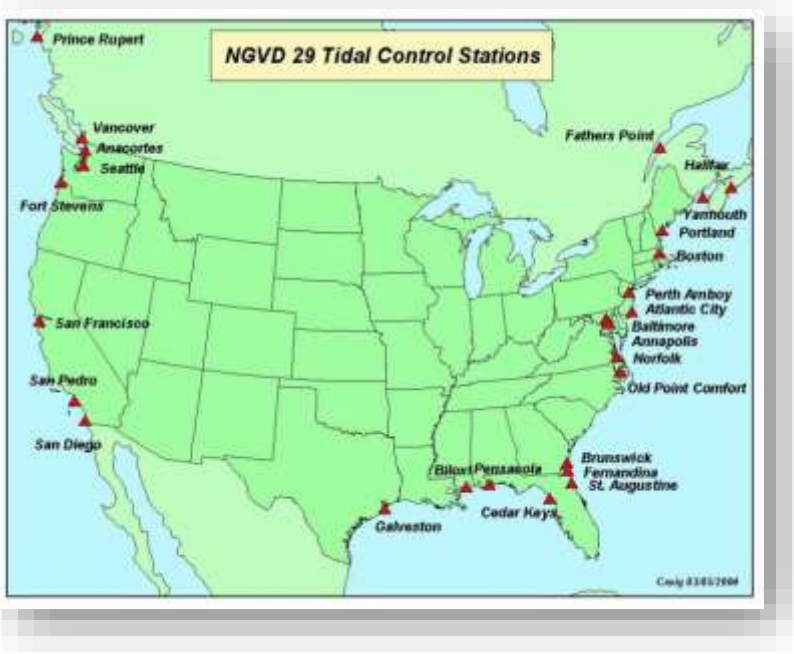
Mapping Fundamentals

Orthometric Datums: NAVD88 and NGVD29



North American Vertical Datum of 1988 (NAVD88):

- Defined by one height (Father's Point, Quebec, Canada)
- Uses geoid as a surface for deriving height
- Affirmed the official civilian vertical datum for the U.S. in 1993



National Geodetic Vertical Datum of 1929 (NGVD29):

- Defined by observed heights of mean sea level measured from 26 tide gauges in the U.S. and Canada
- Surface is distorted to fit mean sea level gauges

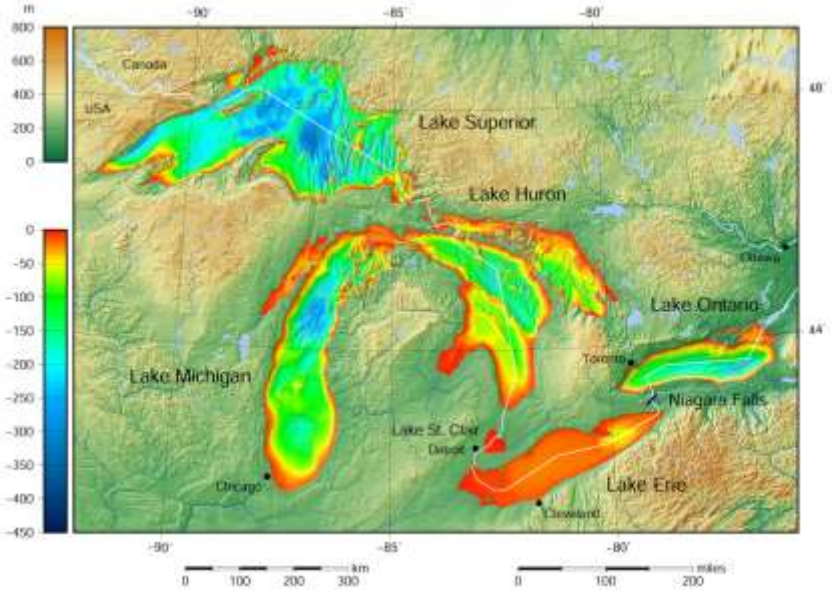
POLL QUESTION

Mapping Fundamentals

Great Lakes Datums

International Great Lakes Datum 1985 (IGLD85)

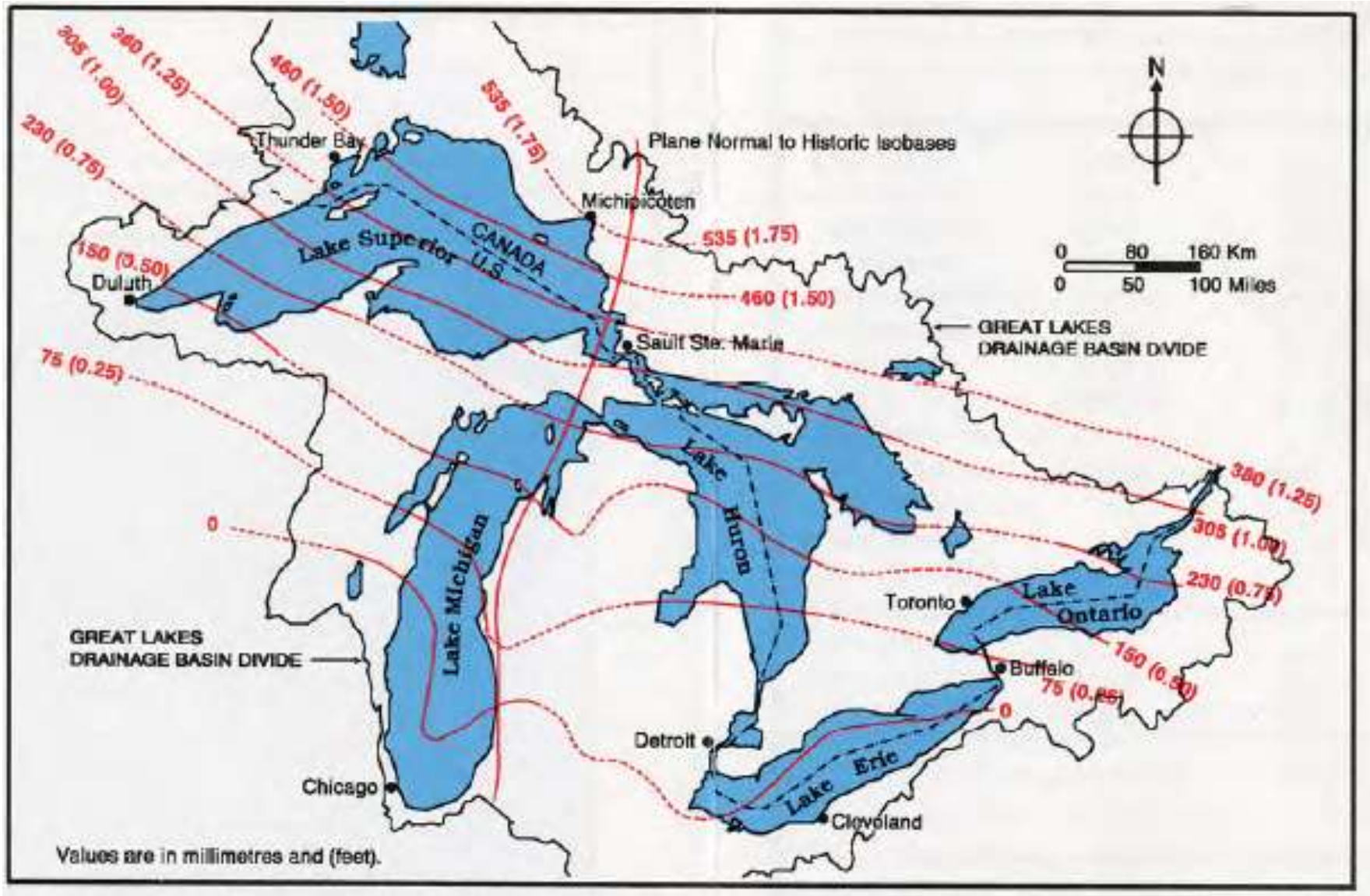
- Defined by one height (Father's Point, Quebec, Canada).
- 1985 represents the central year (1982-1988) for which water information was collected to revise the datum.
- Important for the coordinated measurement of water levels between the United States and Canada.
- Periodically revised due to isostatic rebound.



- First common datum between the United States and Canada was IGLD 1955.
- Revision performed by the Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data which was formed in 1953.
- Implemented in 1992.
- The only difference between IGLD85 and NAVD88 is that IGLD85 bench mark values are given in dynamic height units and NAVD88 values are given in Helmert orthometric height units.

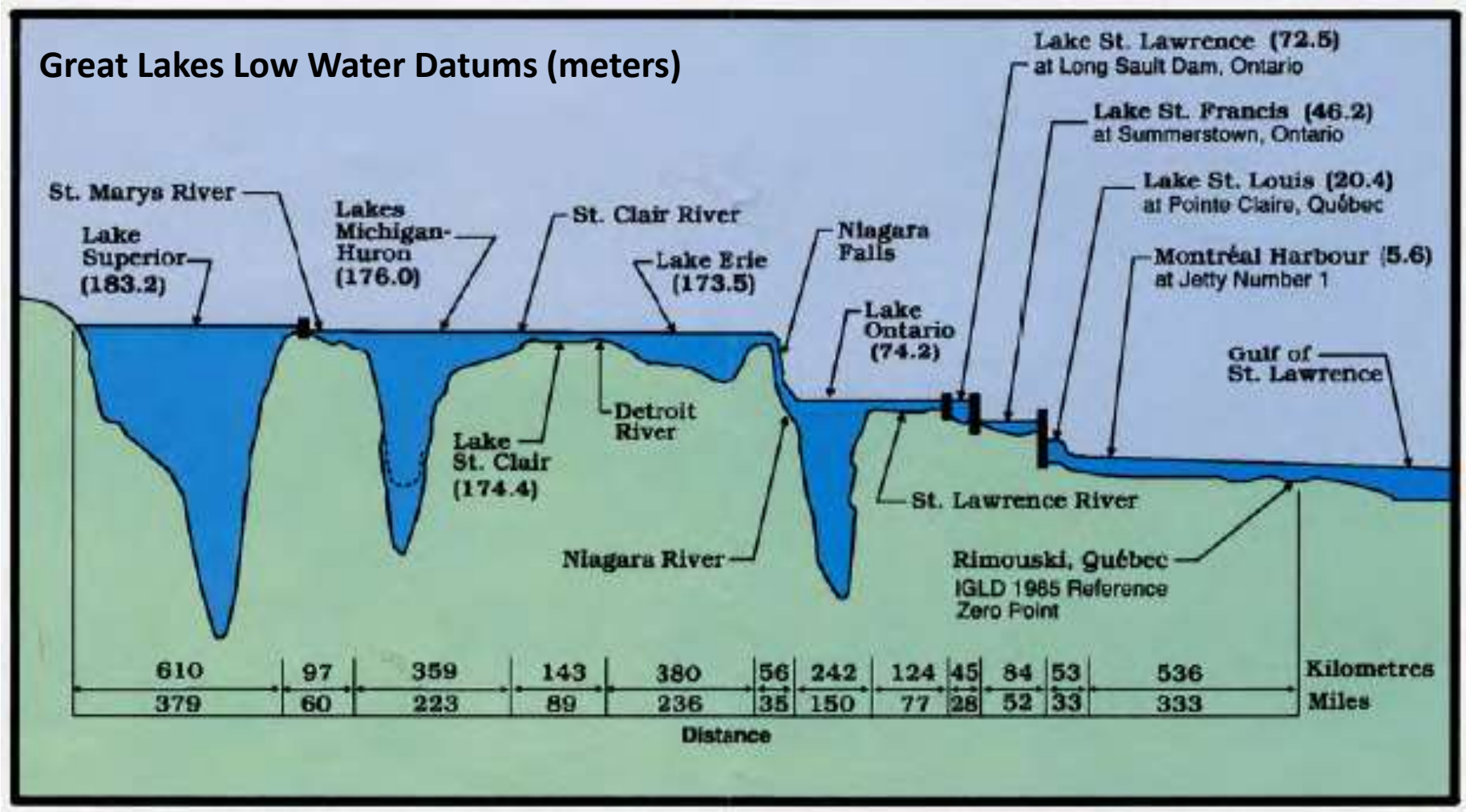
Mapping Fundamentals

International Great Lakes Datum 1985 (IGLD85)



Mapping Fundamentals

International Great Lakes Datum 1985 (IGLD85)



Mapping Fundamentals

International Great Lakes Datum 1985 (IGLD85)

Great Lakes OHWM and LWD (meters)

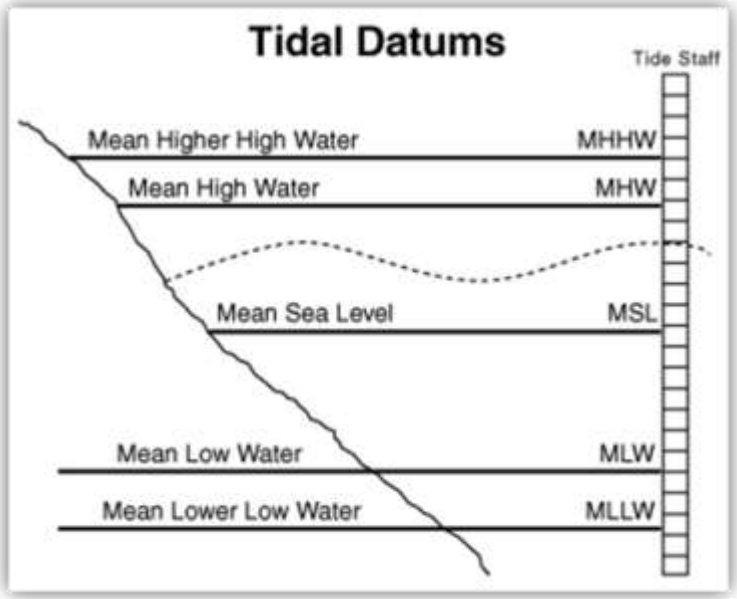
	OHWM IGLD 1985	OHWM IGLD 1955	LWD IGLD 1985	LWD IGLD 1955
Lake Superior	183.8	183.5	183.2	182.9
Lake Michigan	177.2	177.0	176.0	175.8
Lake Huron	177.2	177.0	176.0	175.8
Lake St. Clair	175.6	175.4	174.4	174.2
Lake Erie	174.8	174.6	173.5	173.3
Lake Ontario	75.4	75.2	74.2	74.0

POLL QUESTION

Mapping Fundamentals

Tidal Datums

- A tidal datum is a standard elevation based on some phase of the tide that is used as a reference to measure water levels.
  - Nautical charting
  - Shoreline mapping
  - Bathymetric mapping
  - Boundary delineations

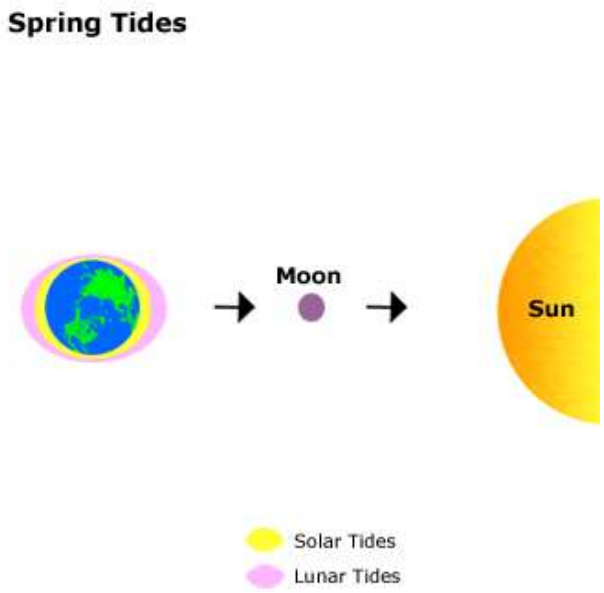


Source: Tidal Datums and Their Applications

- These are local datums and cannot be applied to different areas because of differing hydrographic characteristics.
- Tidal epoch is derived using an averaging technique for a specific time period of 19 years. The current epoch is 1983-2001.
- Most tidal datums are referenced to fixed points called benchmarks.

Mapping Fundamentals

National Tidal Datum Epoch

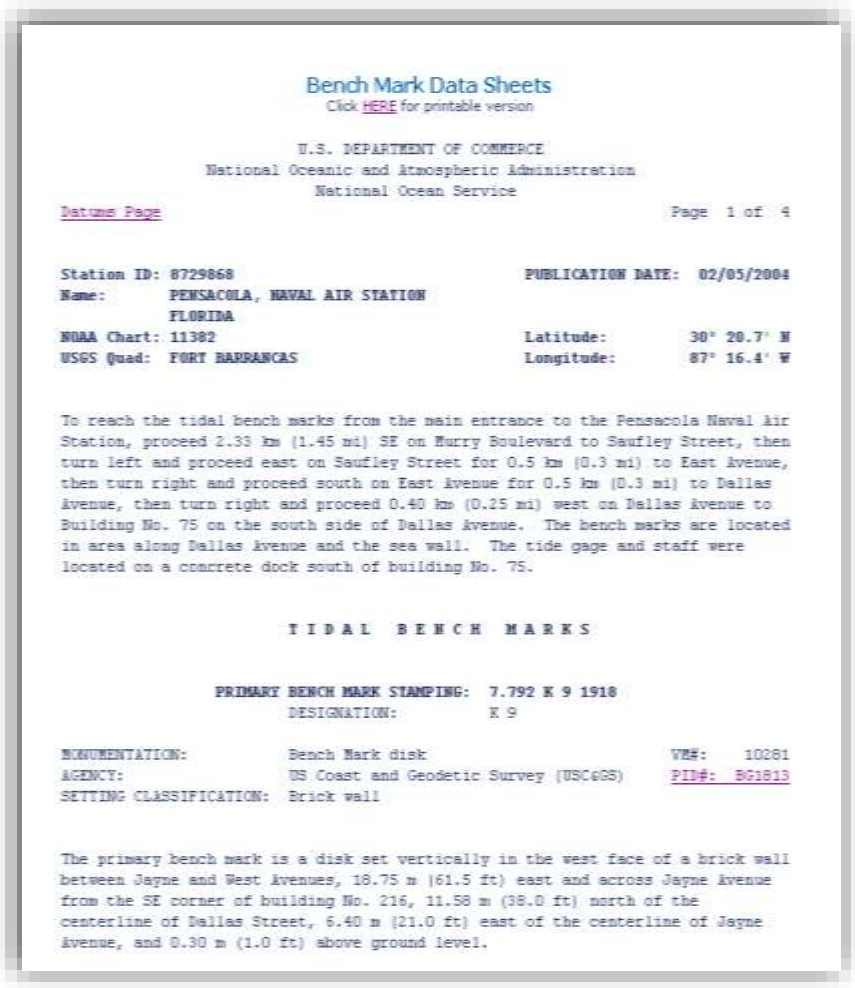


- A specific 19-year period that includes the longest periodic tidal variations caused by the astronomic tide-producing forces
- Averages out long-term seasonal meteorological, hydrologic, and oceanographic fluctuations
- Provides a nationally consistent tidal datum network
- The National Water Level Observation Network (NWLON) provides the data required to maintain the epoch and make primary and secondary determinations of tidal datums

Mapping Fundamentals

Tidal Benchmarks

- A benchmark is a fixed physical object or mark used as a reference for a datum.
- A tidal benchmark is a mark near a tide station to which the tidal datums are referenced.
- Most tidal benchmarks have an orthometric height maintained by the National Geodetic Survey (NGS), and have tidal information maintained by the CO-OPS.
- Visit the NGS or CO-OPs website to Retrieve information about tidal benchmarks.



Bench Mark Data Sheets

Click HERE for printable version

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

Datums Page — Page 1 of 4

Station ID: 8729868 — PUBLICATION DATE: 02/05/2004
Name: PENSACOLA, NAVAL AIR STATION, FLORIDA
NOAA Chart: 11382 — Latitude: 30° 20.7' N
USGS Quad: FORT BARRANCAS — Longitude: 87° 16.4' W

To reach the tidal bench marks from the main entrance to the Pensacola Naval Air Station, proceed 2.33 km (1.45 mi) SE on Murry Boulevard to Saufley Street, then turn left and proceed east on Saufley Street for 0.5 km (0.3 mi) to East Avenue, then turn right and proceed south on East Avenue for 0.5 km (0.3 mi) to Dallas Avenue, then turn right and proceed 0.40 km (0.25 mi) west on Dallas Avenue to Building No. 75 on the south side of Dallas Avenue. The bench marks are located in area along Dallas Avenue and the sea wall. The tide gage and staff were located on a concrete dock south of building No. 75.

TIDAL BENCH MARKS

PRIMARY BENCH MARK STAMPING: 7.792 K 9 1918
DESIGNATION: K 9

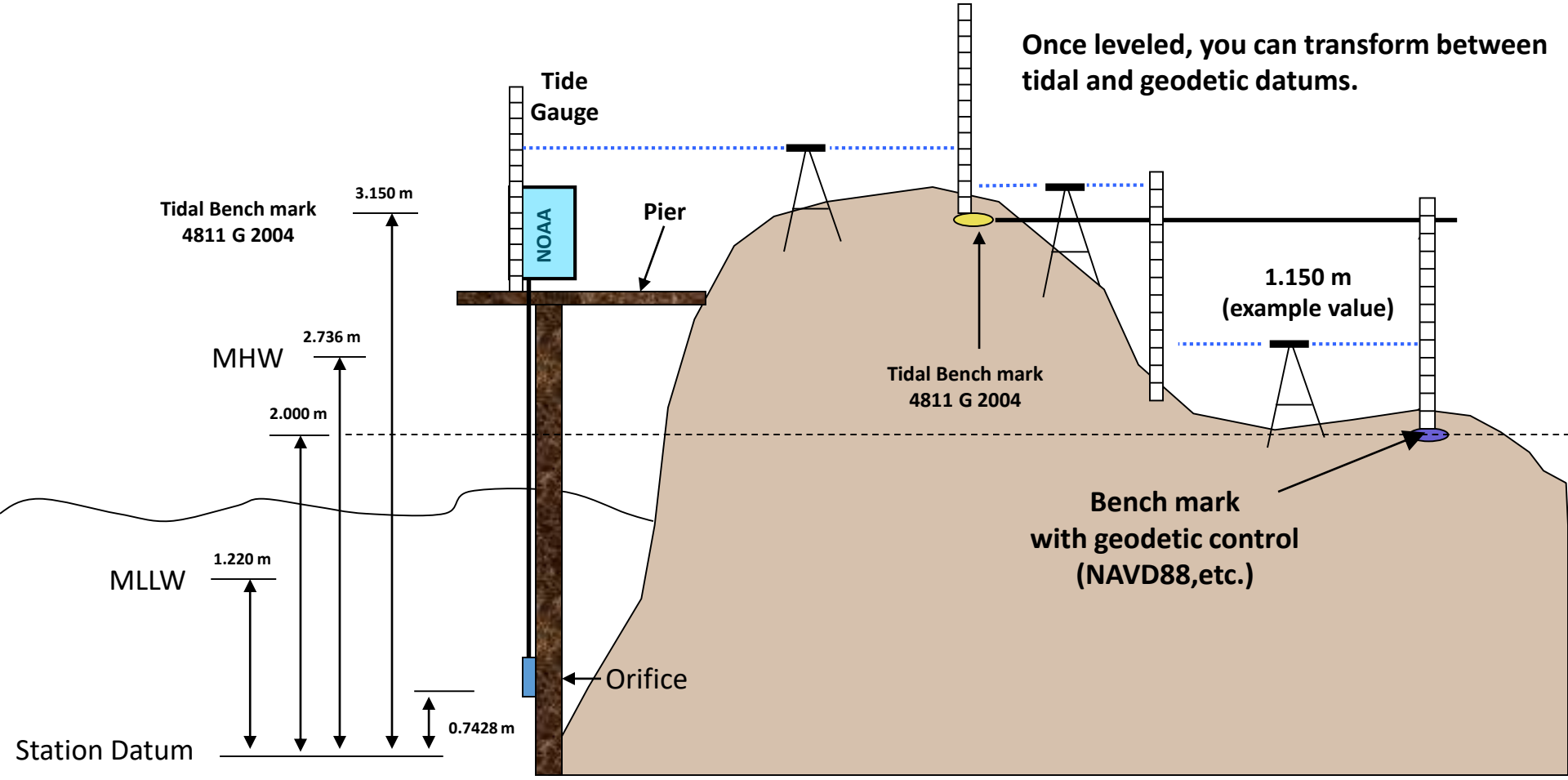
MONUMENTATION: Bench Mark disk — VM#: 10281
AGENCY: US Coast and Geodetic Survey (USC&GS) — PID#: BG1813
SETTING CLASSIFICATION: Brick wall

The primary bench mark is a disk set vertically in the west face of a brick wall between Jayne and West Avenues, 18.75 m (61.5 ft) east and across Jayne Avenue from the SE corner of building No. 216, 11.58 m (38.0 ft) north of the centerline of Dallas Street, 6.40 m (21.0 ft) east of the centerline of Jayne Avenue, and 0.30 m (1.0 ft) above ground level.

Example of a Bench Mark Sheet that provides descriptive information for the selected tide station.

Transformations

Geodetic Tie to Tidal Datums



Transformations

Vertical Datum Transformations

- The **WHY** factor?
    - Creating consistency between elevation values results in a more accurate surface model. Transformations are performed to establish a consistent spatial framework among datasets.

- Example:
    - **Topographic** data are commonly referenced to an orthometric datum (NAVD88)
    - **Bathymetric** data commonly reference a tidal datum (MLLW)

- Working with multiple elevation datasets requires the user to define a common vertical datum so that the elevation values are consistent.

- Tools are available to perform these transformations.

    Conversions need to be done separately for horizontal datums and vertical datums

Transformations

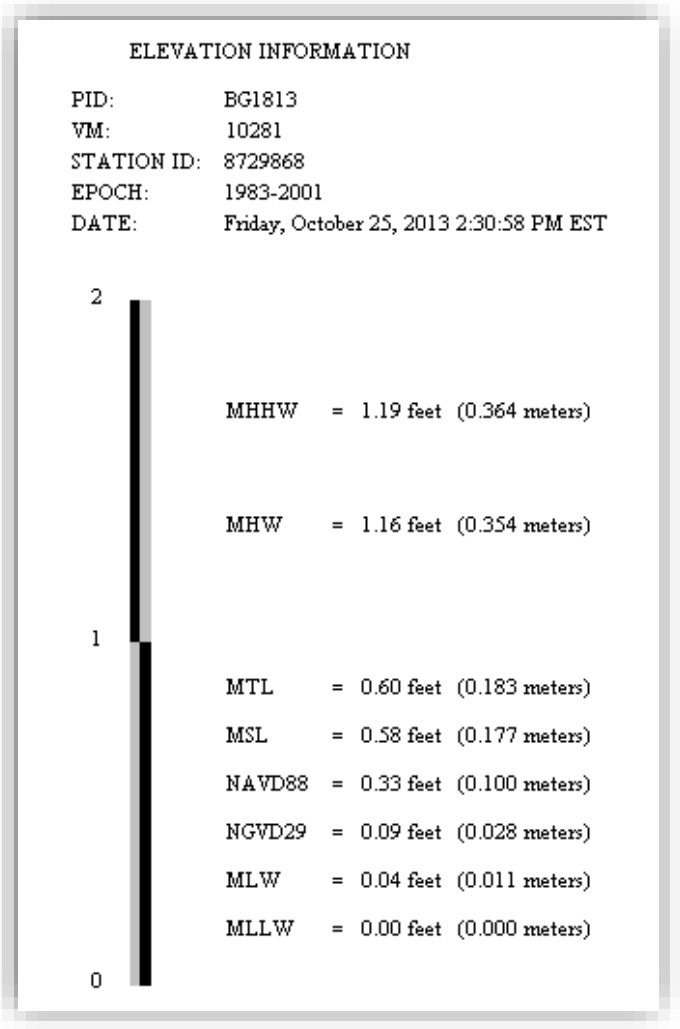
Vertical Datum Transformation Methods

- VERTCON – Translates between NGVD29 and NAVD88
- **CORPSCON** – Converts between horizontal and vertical (orthometric) datums
- VDATUM – Uses a detailed hydrodynamic model to translate between ellipsoidal, orthometric, and tidal datums
- Harmonic Constant Datum Method – Estimates tidal datums using major tidal influences and tidal benchmark data
- Linear Interpolation – Estimates tidal datums using tidal observations at benchmarks and interpolating between tide stations
- Integration with No Conversion – No relationship between datums is established; datums assumed to be equal

Transformations

NGS Tidal and Orthometric Elevations Tool Kit

- Will display tidal and orthometric elevations of a specific survey control mark.
- Displayed will be the differences between the published NGS's NAVD88 and NGVD29, and the CO-OPS' MLLW datums.
- User can enter "PID" (control mark identifier) or latitude and longitude.
- Entering lat/long coordinates will generate a list of PIDs within a 25 mile radius.
- *NGS Geodetic Tool Kit: Tidal and Orthometric Elevations – www.ngs.noaa.gov/TOOLS/*



Mapping Fundamentals

National Spatial Reference System (NSRS)

- A consistent national coordinate system that specifies latitude, longitude, height, scale, gravity, and orientation throughout the nation

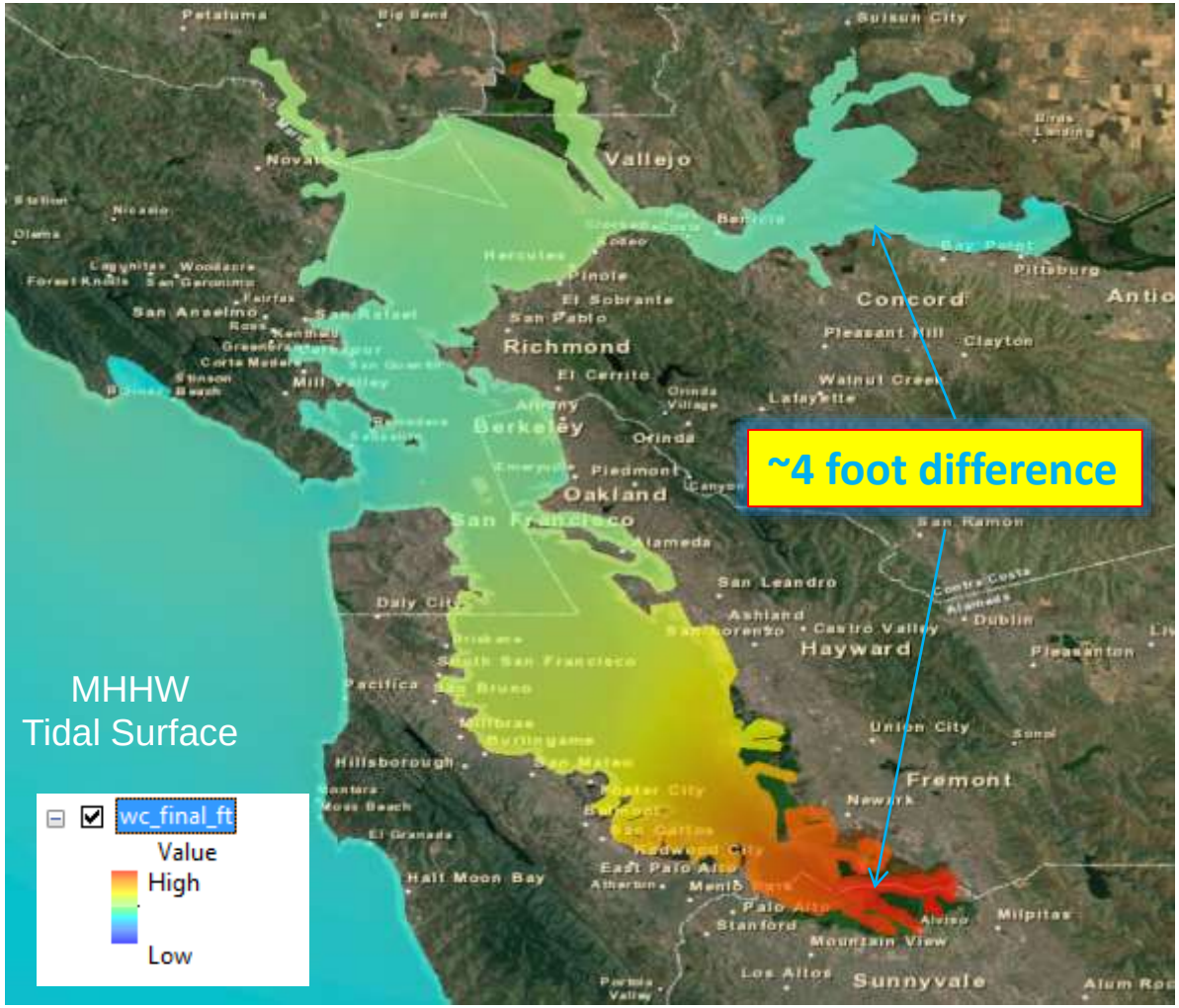
- Managed by the NOAA National Geodetic Survey

- NSRS consists of the following:
  - A consistent, accurate national shoreline
  - National Continuously Operating Reference Stations (CORS)
  - Network of permanently marked points
  - Set of accurate models describing the geophysical processes affecting spatial measurements

www.ngs.noaa.gov

The Ocean Is Not a Flat Surface

(especially in bays and estuaries)



The Ocean Is Not a Flat Surface

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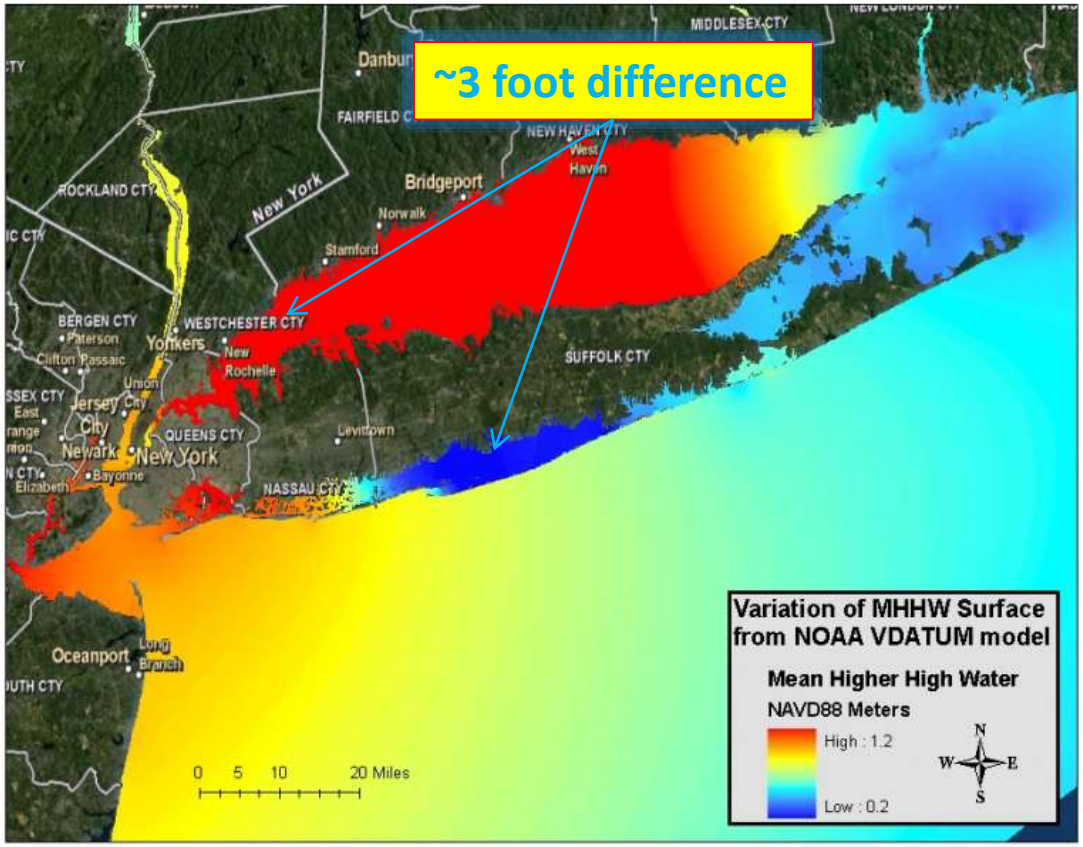
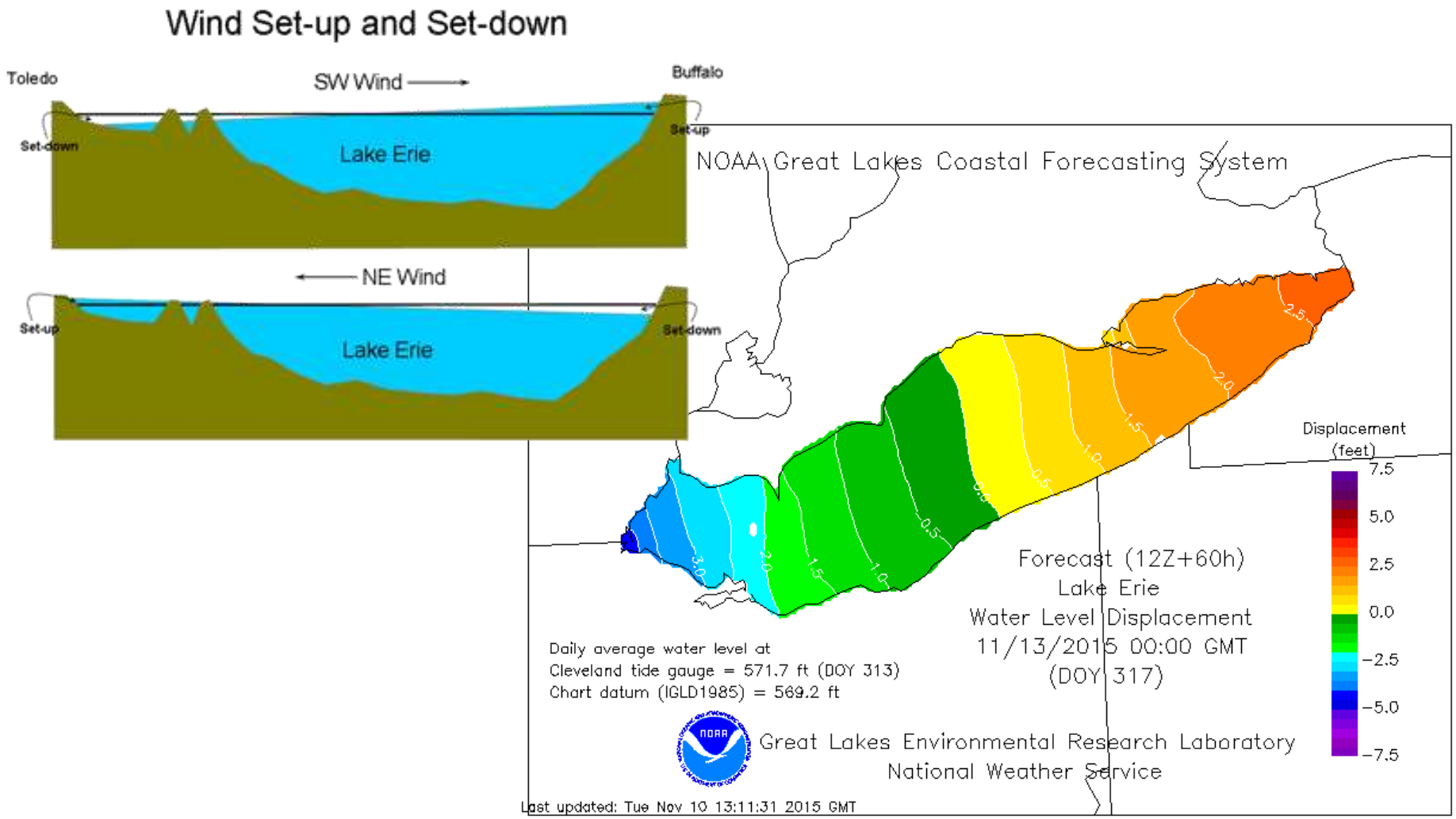


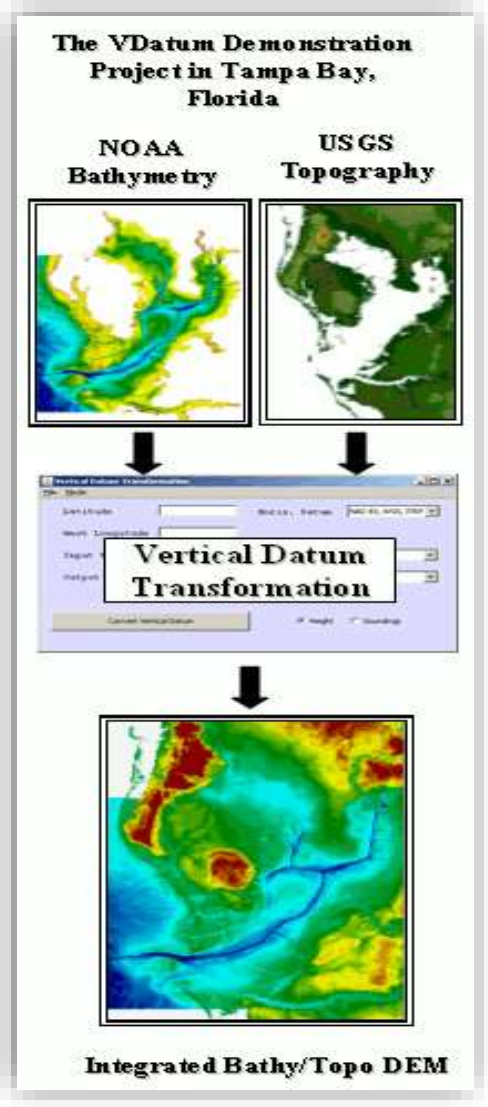
The Great Lakes are Not Flat Surfaces Either



Datum Transformations

Using VDatum to convert between Tidal, Orthometric, and Ellipsoidal datums

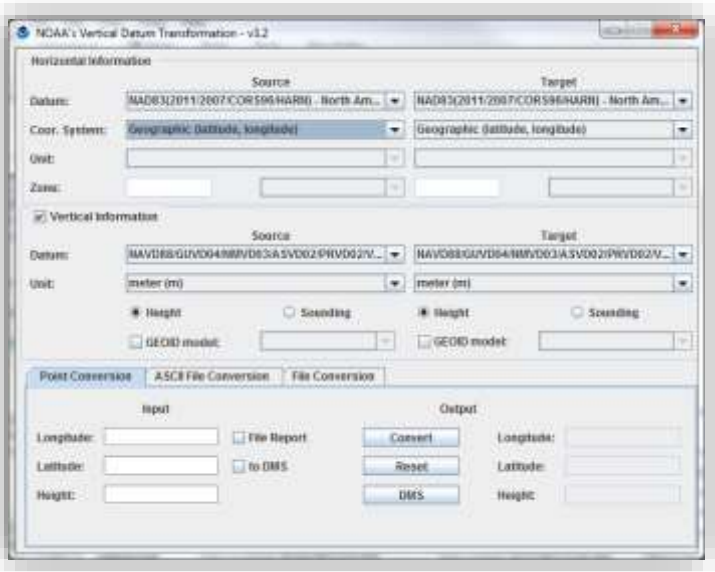
- Vertical Datum Transformation Tool
- Developed jointly by NOAA's Office of Coast Survey and NGS
- Provides a method to accurately combine topographic (orthometric) and bathymetric (tidal) elevation data
- Application is limited to the region it was developed for
- Download Software and Documentation
  - ***vdatum.noaa.gov/welcome.html***

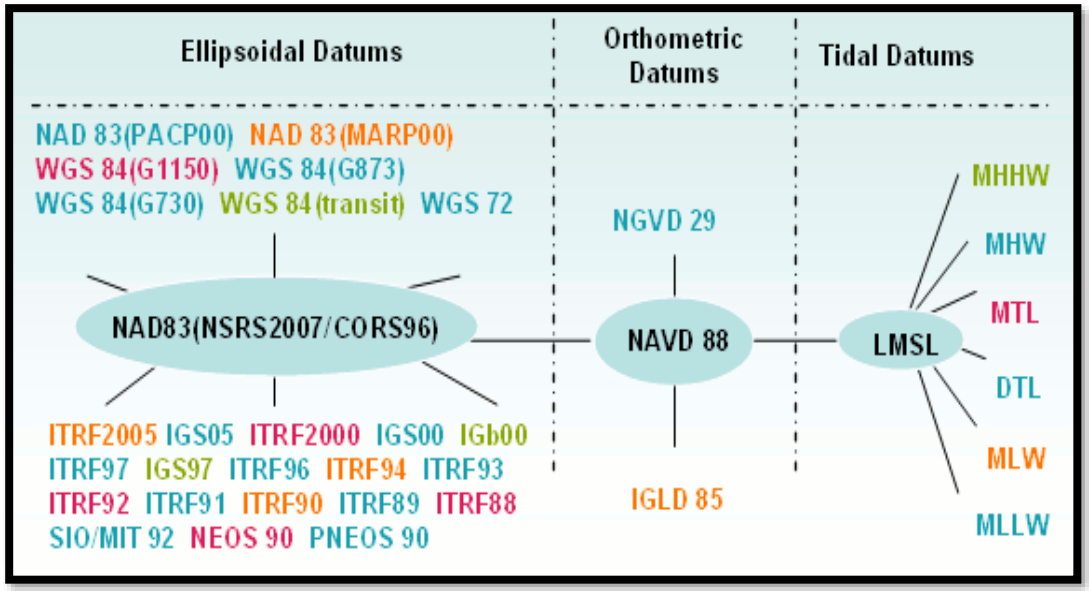


Datum Transformations

How Does VDatum Work?

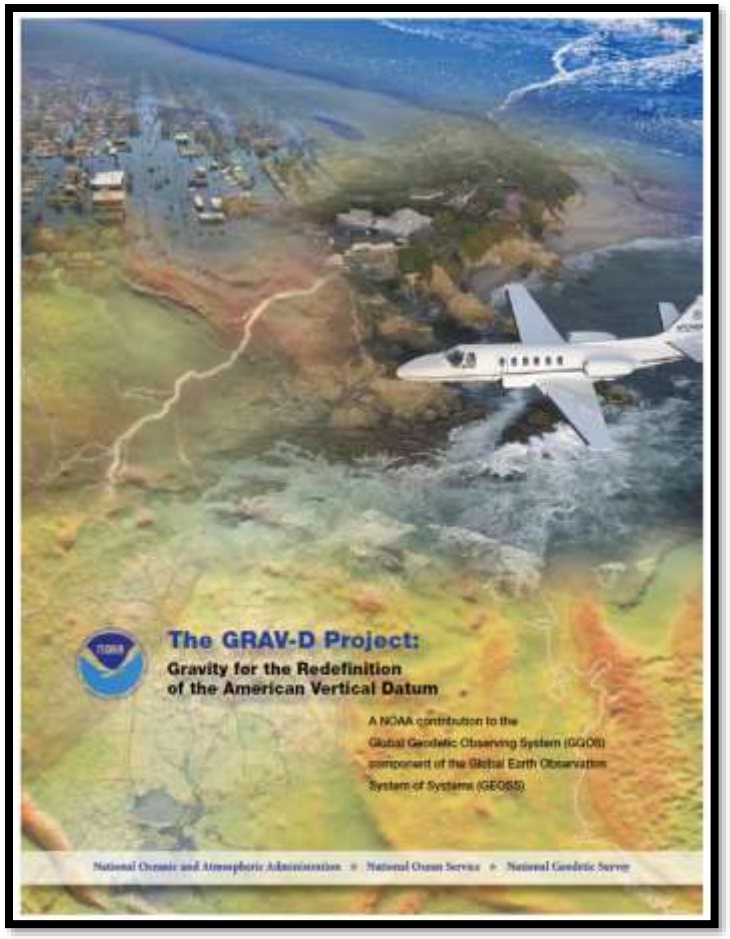
- Java Runtime Environment (JRE) must be installed to run VDatum (*http://java.sun.com/*)
- VDatum can operate in an individual or batch mode
- User input includes: Horizontal Datum, Input Vertical Datum, Output Vertical Datum, Units of original vertical datum, Type of elevation data





Mapping Fundamentals

Gravity for the Redefinition of the American Vertical Datum (GRAV-D)



http://www.ngs.noaa.gov/GRAV-D/

GRAV-D is a proposal by the National Geodetic Survey to re-define the vertical datum of the US by 2022

- **A high-resolution "snapshot" of gravity in the US**
  - predominantly airborne campaign, a cost of ~39 Million dollars
- **A low-resolution "movie" of gravity changes**
  - primarily a terrestrial campaign and will mostly encompass episodic re-visits of absolute gravity sites
- **Regional partnership surveys**
  - NGS seeks to collaborate with local (governmental, commercial, and academic) partners throughout the GRAV-D project.

CLOSING COMMENTS

- To suggest future CTP web meeting topics, please contact Alan Lulloff at *alan@floods.org*
- … or type a suggested topic into the Questions panel today
- CFM CECs through ASFPM will be automatically applied. If you *require* a Certificate of Attendance, please contact *gisjason@floods.org*
- Follow-up email will be sent in about a week

Thank You for Joining Us!