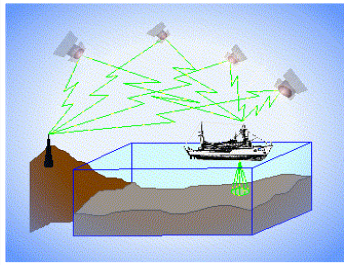
VDatum

Vertical Datum Transformation Tool

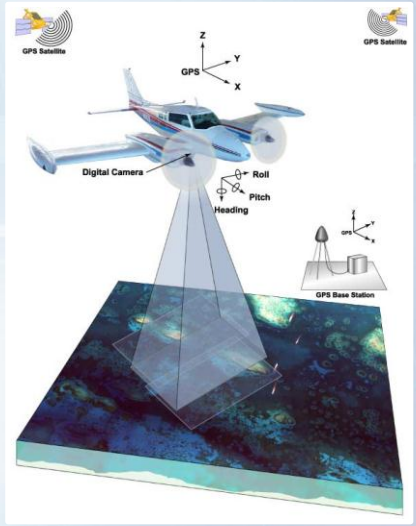
National Oceanic and Atmospheric Administration

What Vertical Datum is My Data in?

Ellipsoidal Datums



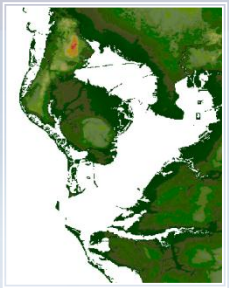
RTK-GPS vertical referencing Hydrographic Surveys



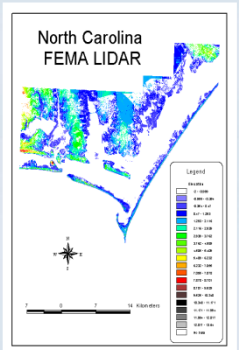
Lidar

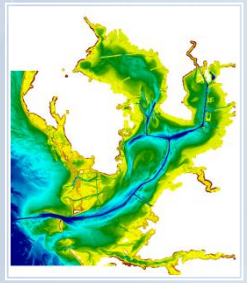
GPS

Orthometric Datums

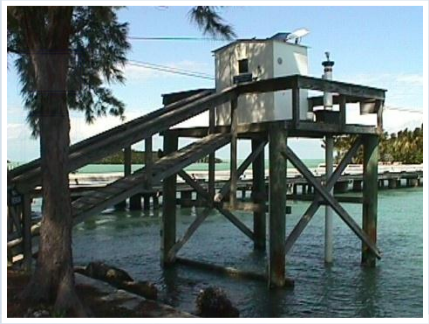


USGS Topography

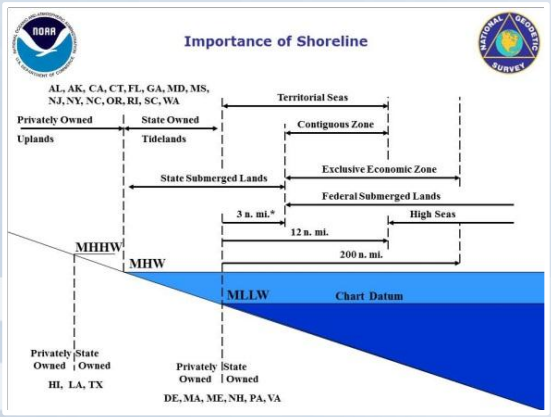




NOAA Bathymetry (MLLW)



Tidal Datums



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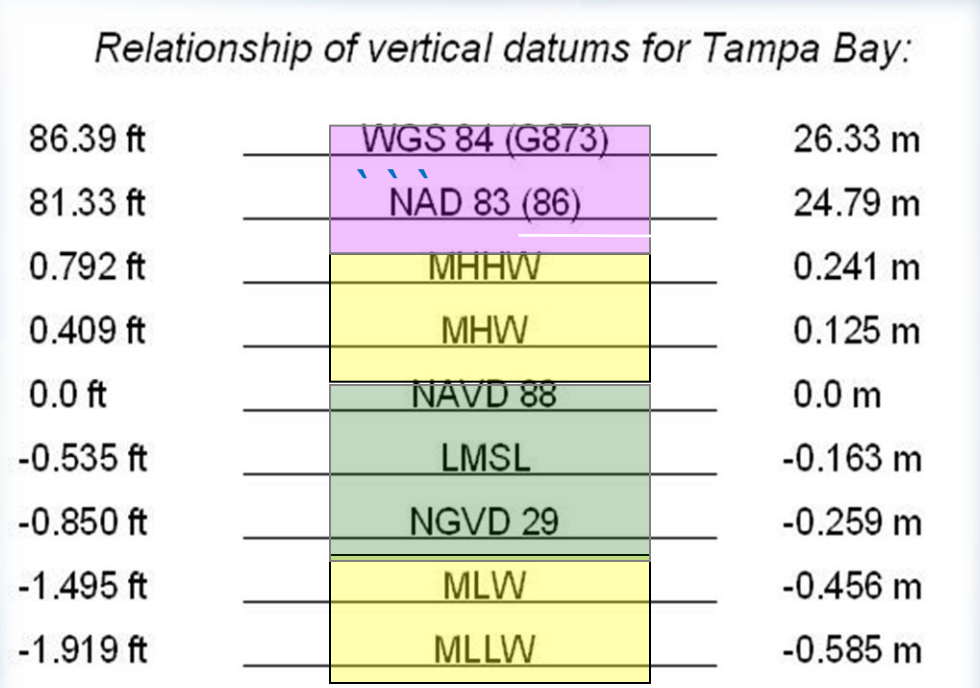
All elevation data is referenced to a vertical datum.

BUT ***there are a many different vertical datums in use around the nation***



For elevation data sets to be blended together they must be referenced to same vertical datum.

Ellipsoid Datums

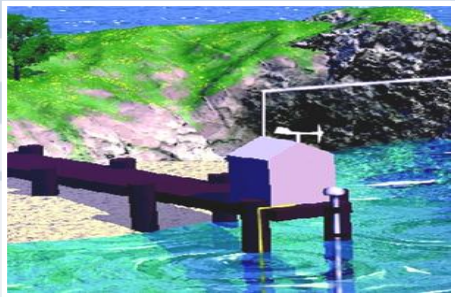
ITRF,
WGS 84,
NAD 83 (NSRS)

Orthometric Datums

NAVD 88,
NGVD 29

Tidal Datums

MHHW, MHW, MTL, DTL, LMSL, MLW, MLLW



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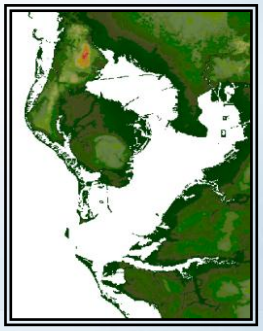
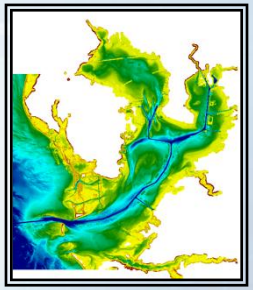
Development and Use of VDatum

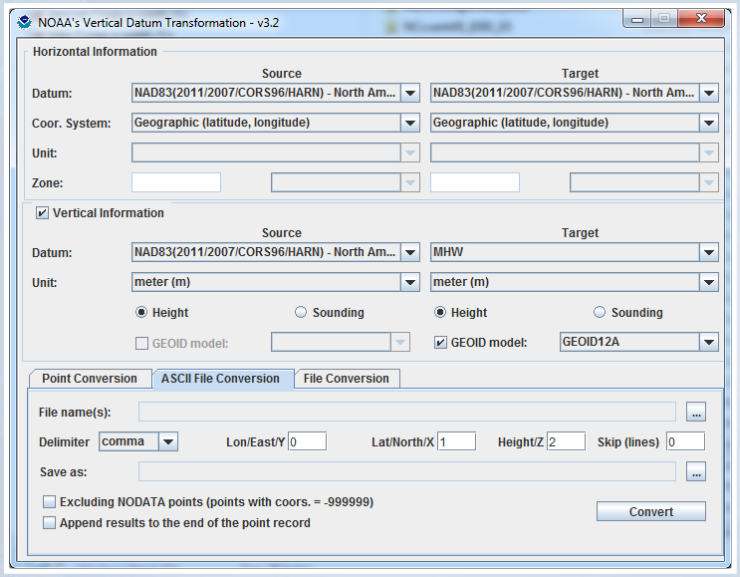
Mapping the Land-Sea Interface:
VDatum converts elevation data (heights and soundings) among different vertical datums

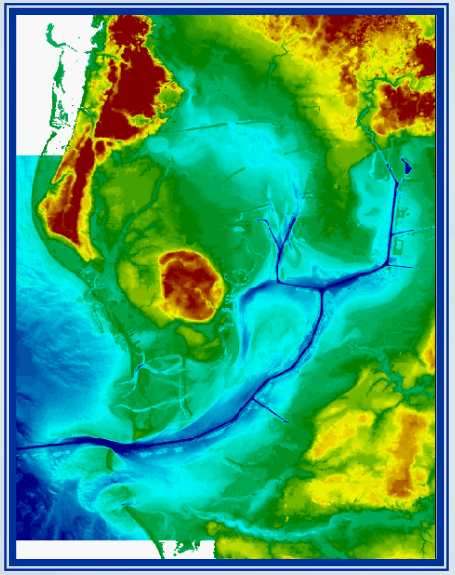


USGS Topography



NOAA Bathymetry





VDatum is a Java application developed jointly by :

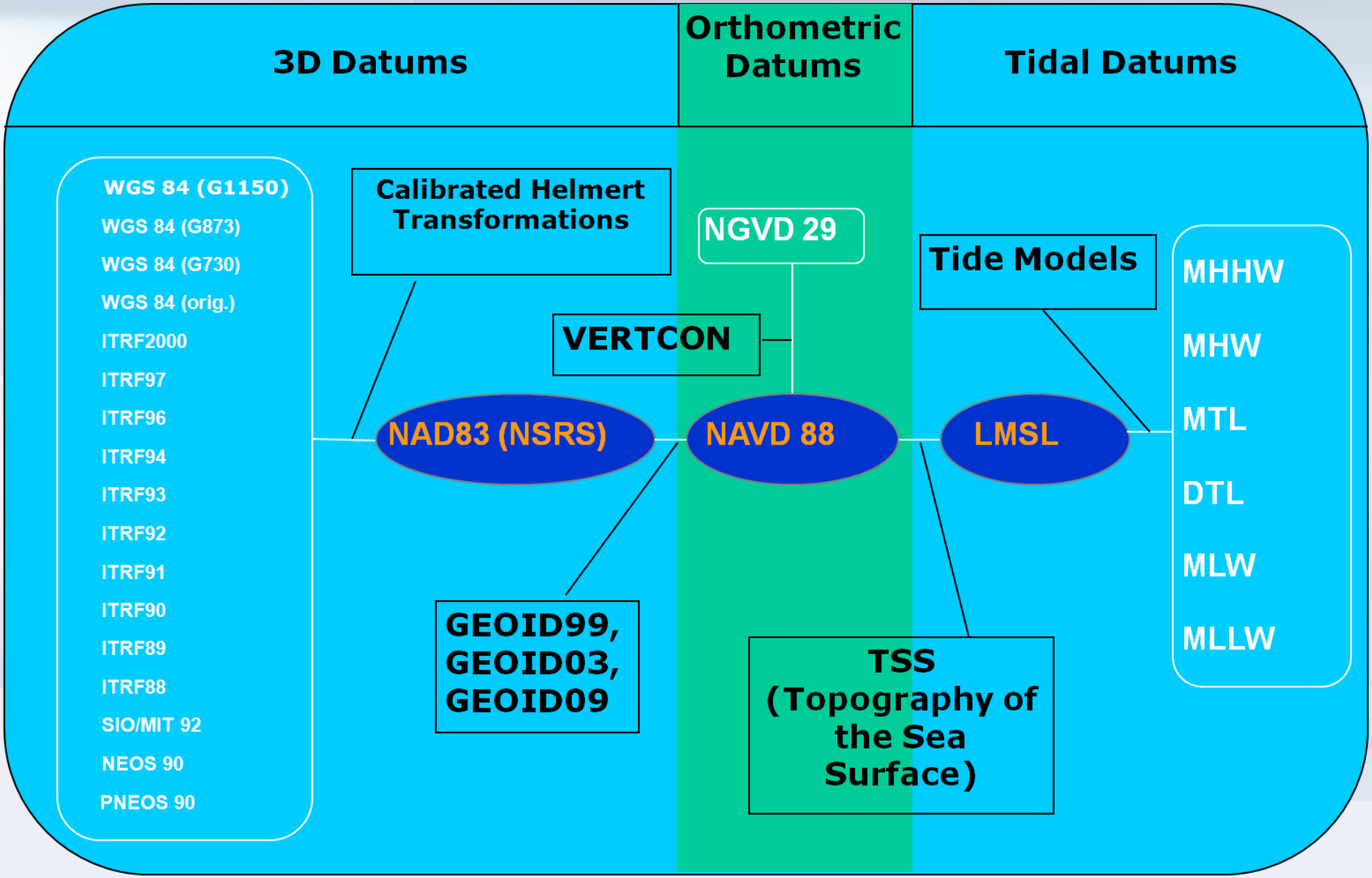
- **National Geodetic Survey (NGS)**
- **Office of Coast Survey (OCS)**
- **Center for Operational Oceanographic Products & Services (CO-OPS)**

National Oceanic and Atmospheric Administration

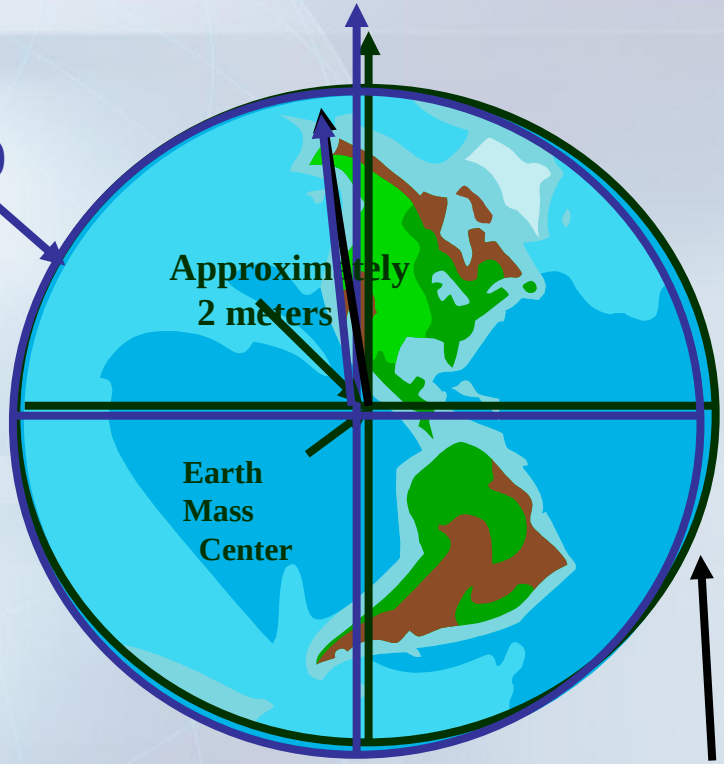
3 Categories of Vertical Datums:

- **3D/Ellipsoidal Datums:**
  - Realized through space-based systems, such as GPS
- **Orthometric Datums:**
  - Based on a form of mean sea level
- **Tidal Datums:**
  - Based on tidally-derived surfaces such as high or low water

Vertical Datum Transformation "Roadmap"



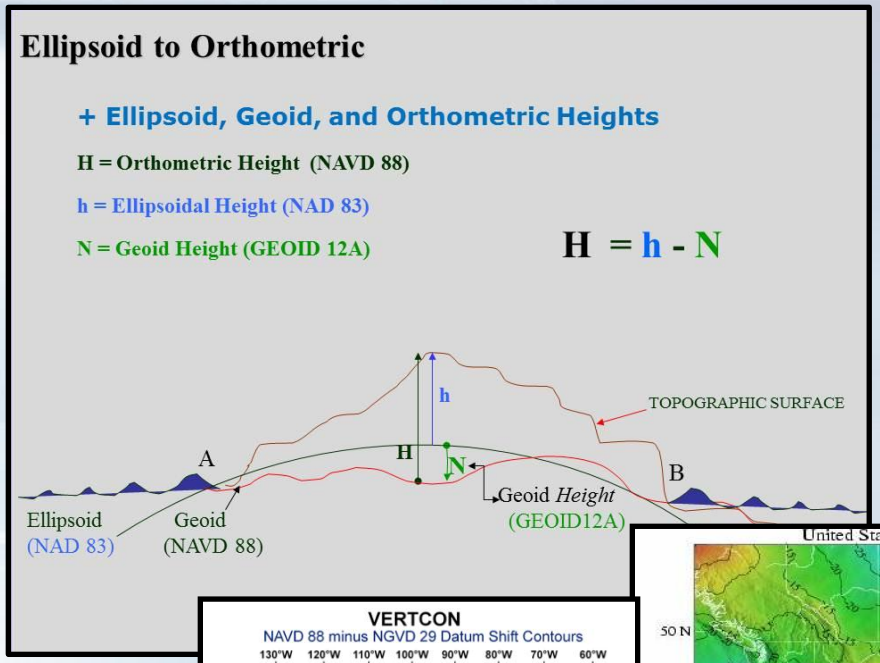
3D/Ellipsoid Datums



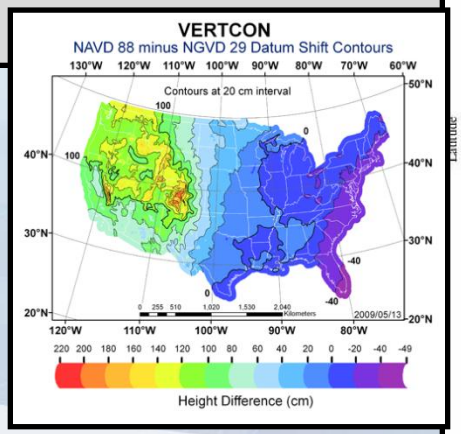
The GRS80 ellipsoid's origin is approximately 2m from WGS84 ellipsoid's. The Clarke 1866 ellipsoid's origin is approximately 236 m from WGS84 ellipsoid's

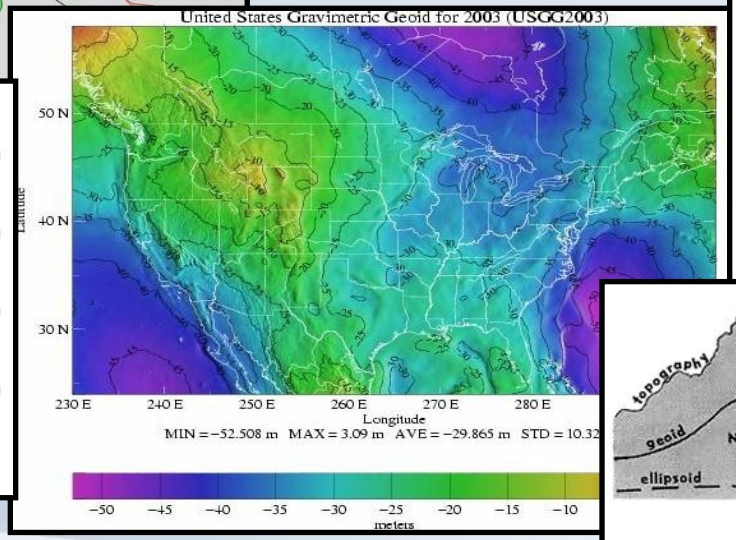
- Calculation of geographic position on this irregular surface is very complex. A simpler model is needed.
- This simplified mathematical surface is the *ellipsoid*.
- An ellipsoid approximates the shape of the earth, a datum defines the position of the ellipsoid relative to the center of the earth. A datum provides a frame of reference for measuring locations on the surface of the earth.

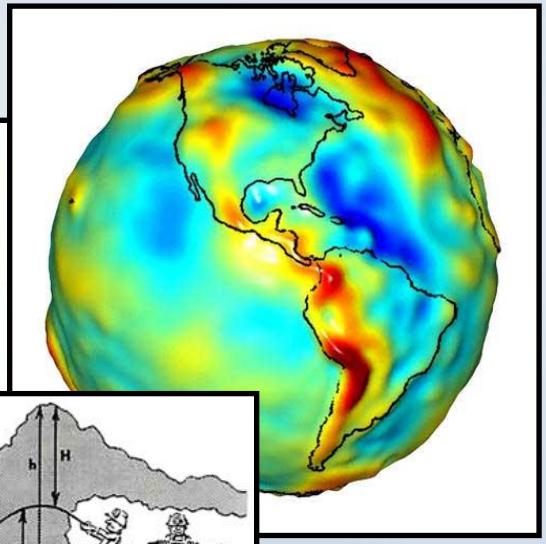
Orthometric Datums and the GEOID

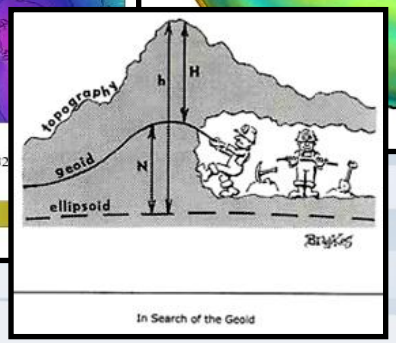


- NAVD88 is based on an adopted elevation at Point Rimouski (Father's Point). It uses Helmert orthometric heights as an approximation to true orthometric heights.
- GEOID: "The *equipotential surface* of the Earth's gravity field which best fits, in the least squares sense, (global) mean sea level."
- Can't see the surface or measure it directly.
- Can be modeled from gravity data as they are mathematically related.









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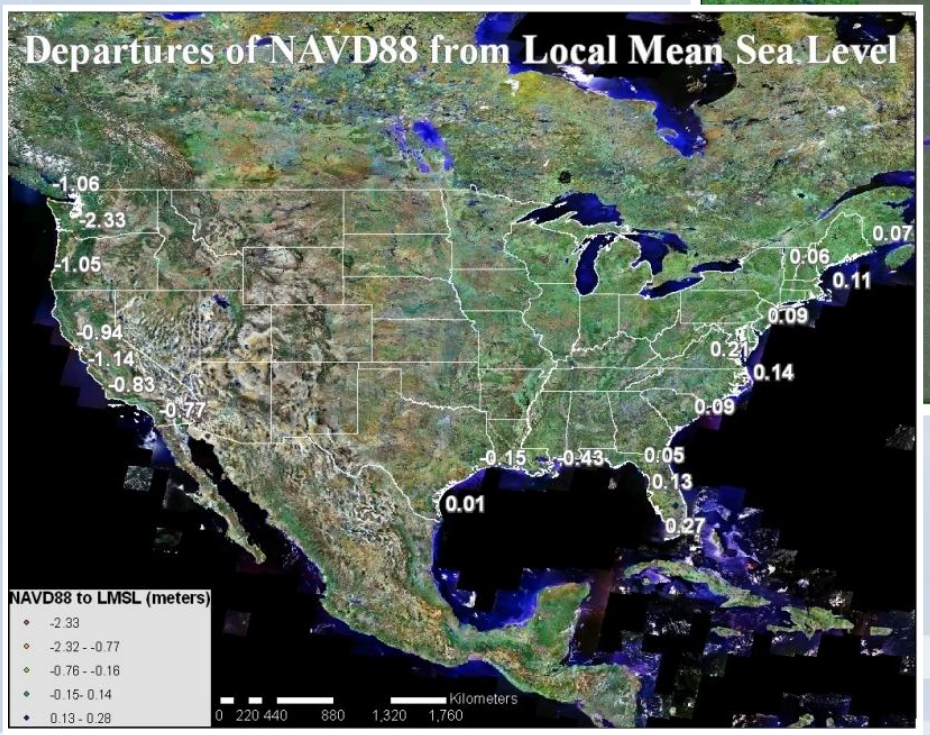
biquadratic interpolation

Topography of the Sea Surface

The Topography of the Sea Surface (TSS) is defined as the elevation of the North American Vertical Datum of 1988 (NAVD88) relative to local mean sea level (LMSL).

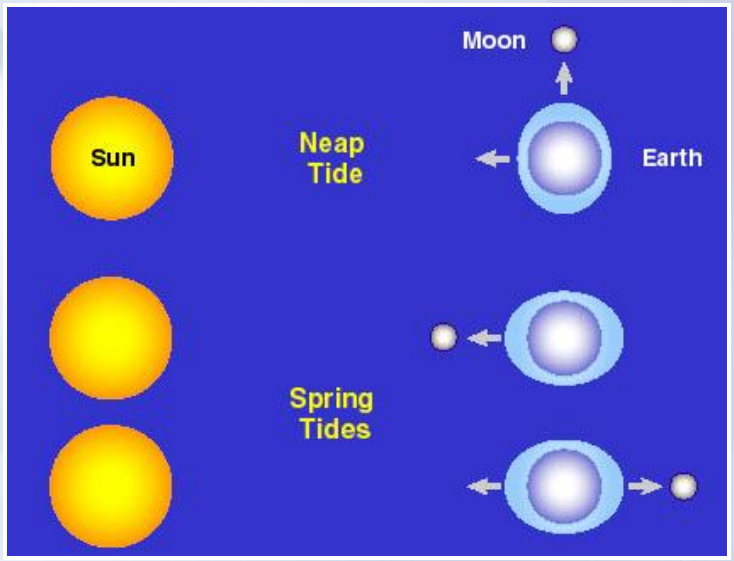
- This grid provides compensation for the local variations between a mean sea level surface and the NAVD88 geopotential surface.
- A positive value specifies that the NAVD88 reference value is further from the center of the Earth than the local mean sea level surface.



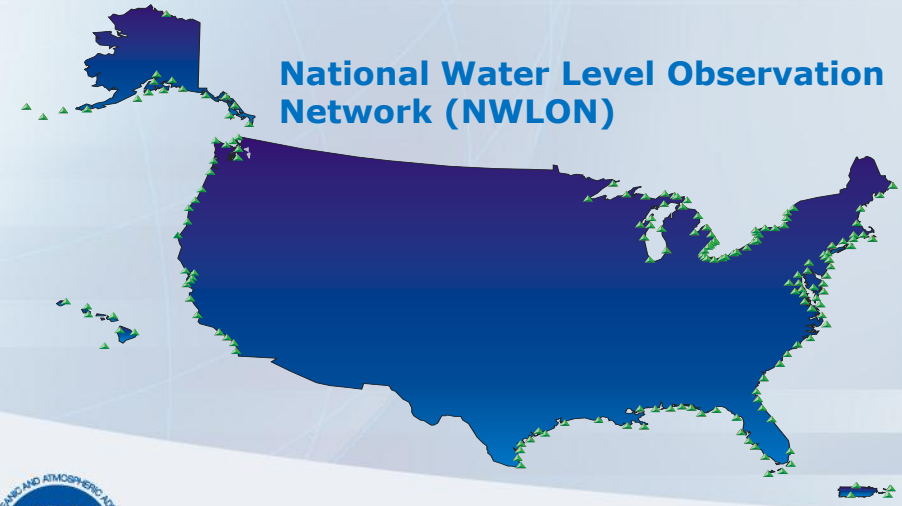
National Oceanic and Atmospheric Administration

bilinear interpolation

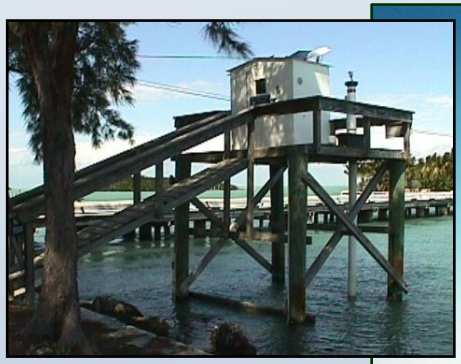
Tidal Datums



- A vertical datum is called a tidal datum when it is defined by a certain phase of the tide.
- National Tidal Datum Epoch (NTDE): is a specific 19-year period that spans the longest periodic tidal variations resulting from astronomical tide-producing forces.
- The fundamental base from which most coastal and marine boundaries are determined.
- Also important for referencing soundings and depicting shorelines on nautical charts.

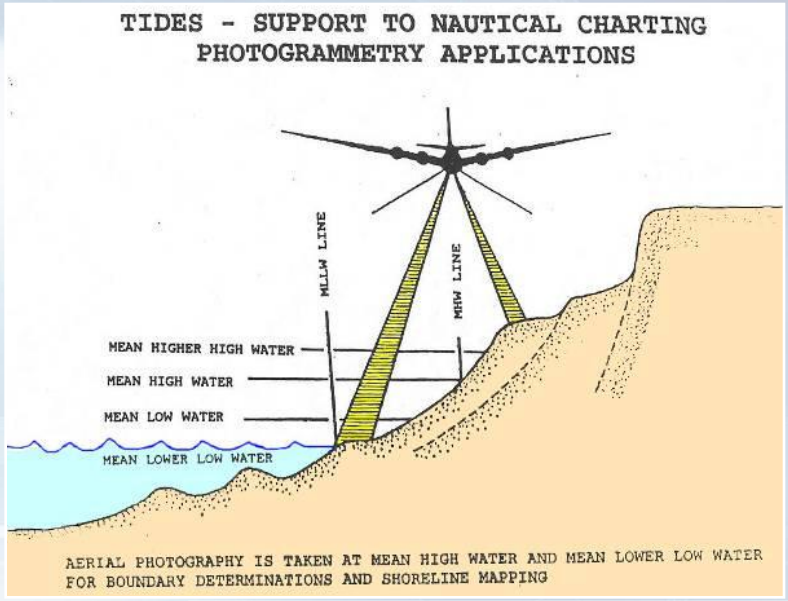


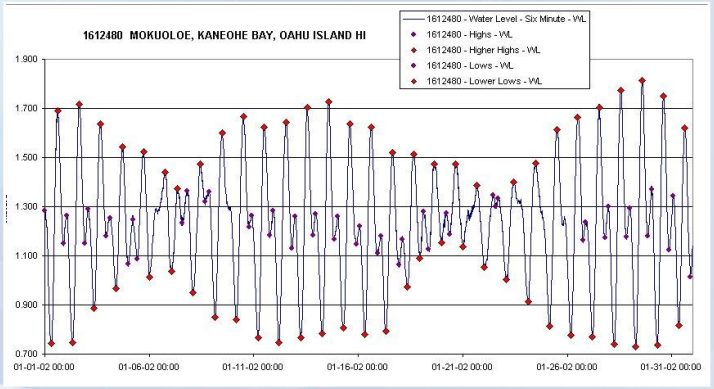
National Water Level Observation Network (NWLON)



National Oceanic and Atmospheric Administration

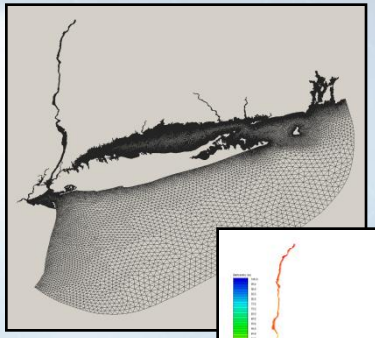
Tidal Datums



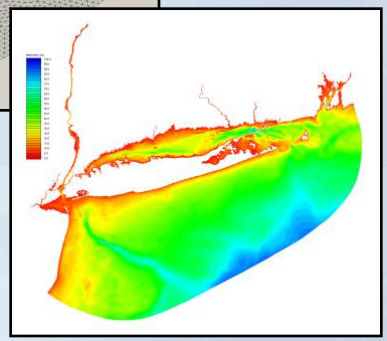


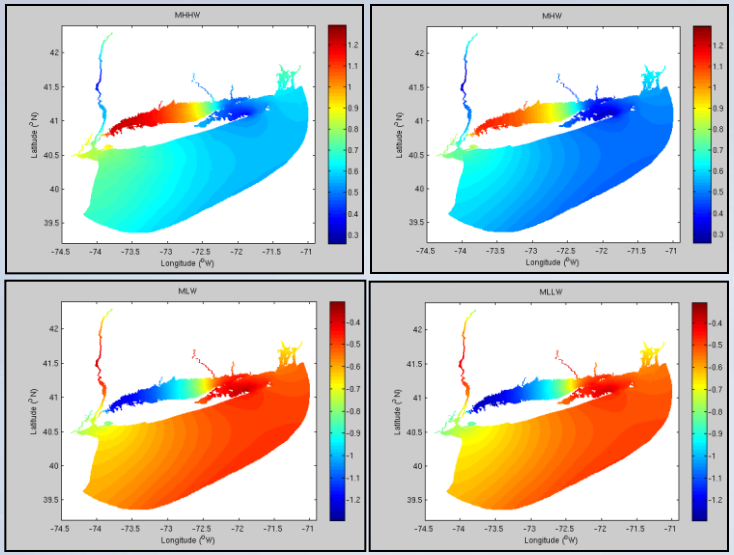
- Mean Higher High Water (MHHW): defined as the arithmetic mean of the higher high water heights of the tide over a specific 19-year Metonic cycle denoted as the NTDE.
- **Mean High Water (MHW):** defined as the arithmetic mean of the high water heights observed over a specific 19 year cycle.
- Mean Sea Level (MSL): defined as the arithmetic mean of hourly heights observed over a specific 19 year cycle.
- Mean Low Water (MLW): defined as the arithmetic mean of the low water heights observed over a specific 19 year cycle.
- **Mean Lower Low Water (MLLW):** defined as the arithmetic mean of the lower low water heights of the tide observed over a specific 19 year cycle.
- Mean Tide Level (MTL): a tidal datum which is the average of Mean High Water and Mean Low Water.
- Diurnal Tide Level (DTL): a tidal datum which is the average of Mean Higher High Water and Mean Lower Low Water.

Tidal Datums and Hydrodynamic Modeling

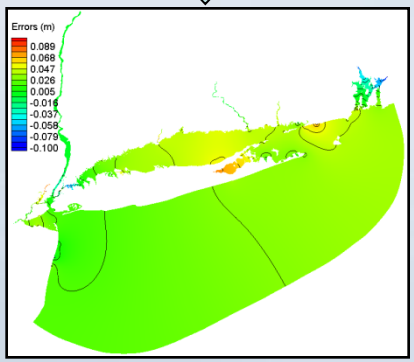


Finite Element grid is created and populated with bathymetry

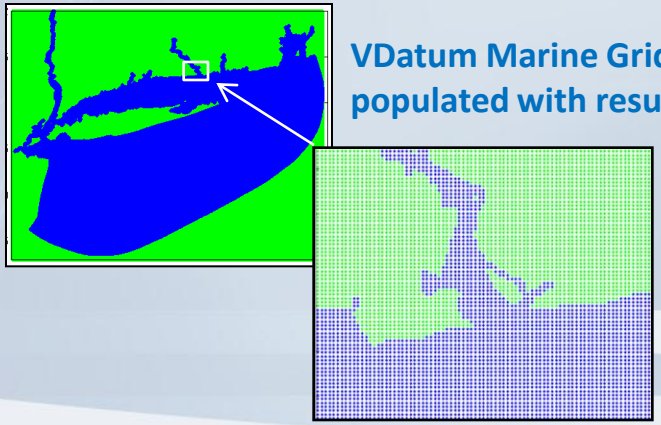




Tidal Datum fields are derived from ADCIRC (Advanced Circulation) Model, simulations are made on cluster computers at NOAA's Earth System Research Laboratory



Correct results by spatially interpolating errors with TCARI (Tidal Constituent and Residual Interpolation)



VDatum Marine Grid is populated with results

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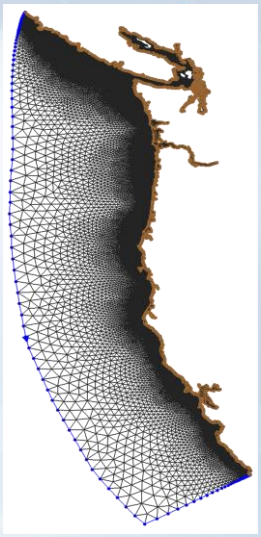
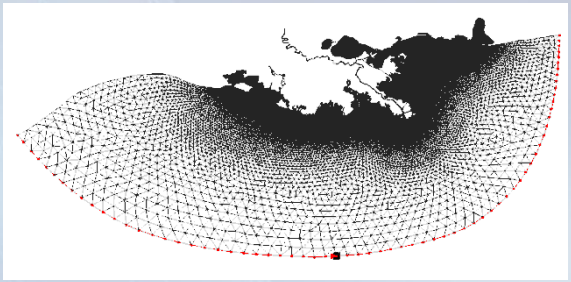
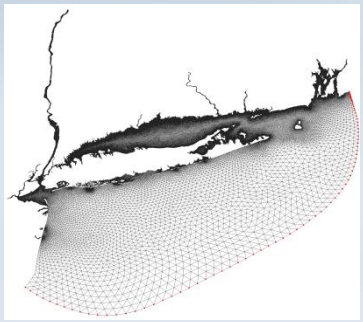
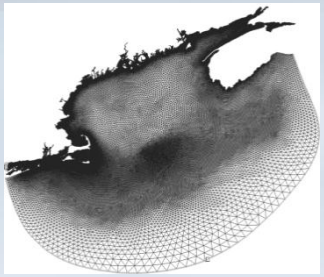
bilinear interpolation

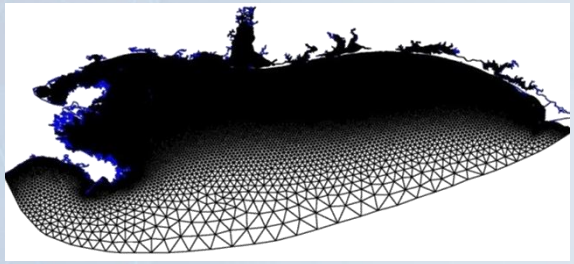
ADCIRC Modeling in Support of VDatum

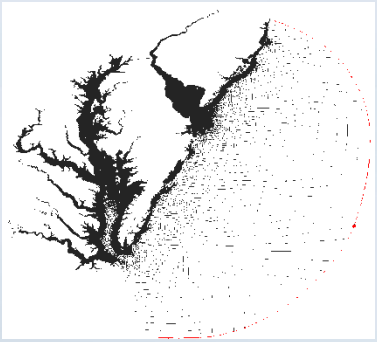


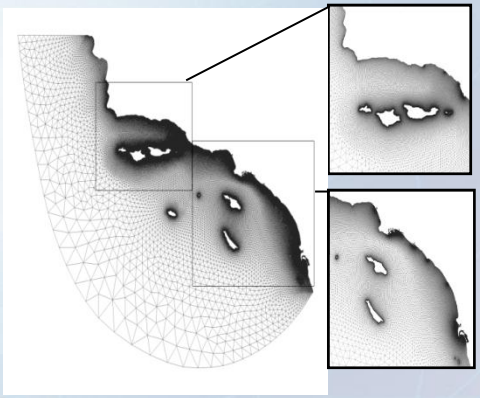


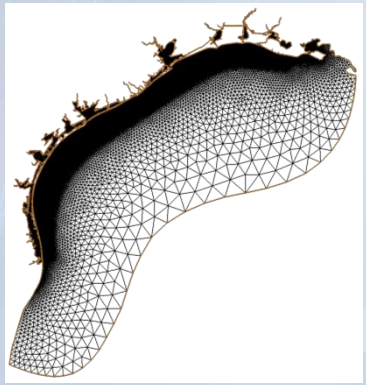


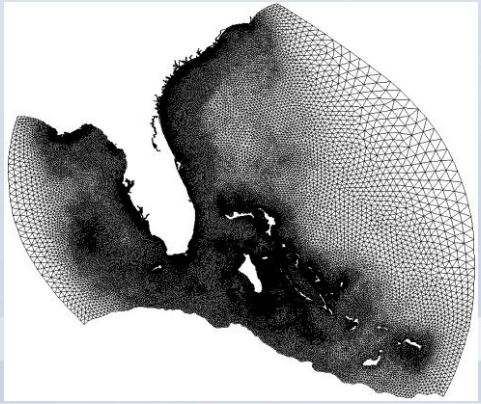


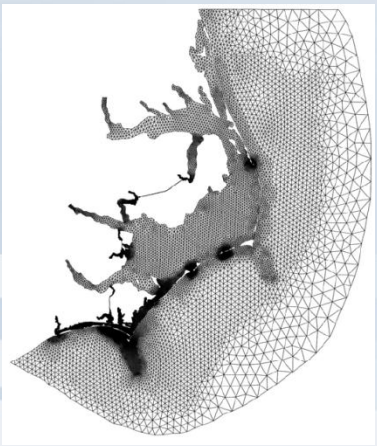












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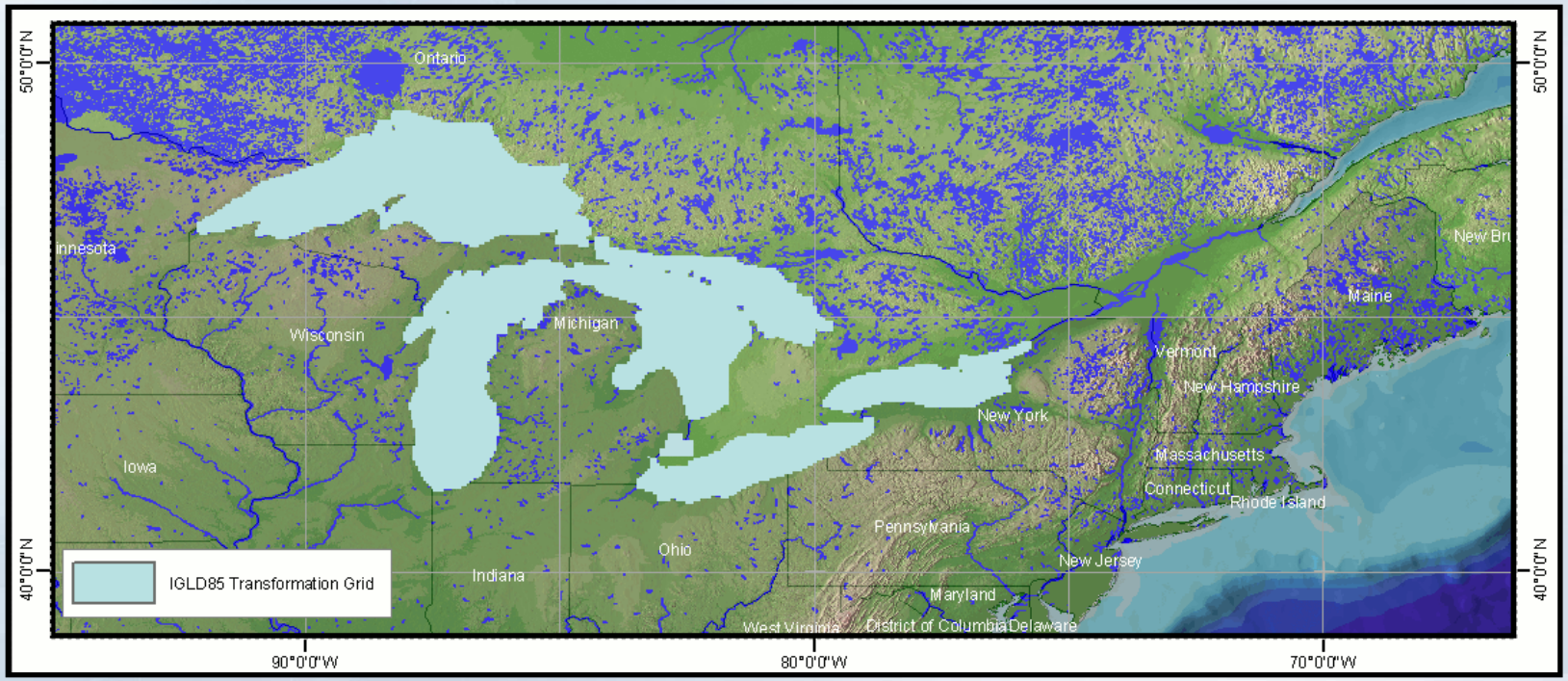
VDatum: IGLD85

- Conversions between IGLD 85 and NAVD 88 are provided based on the NAVD 88 gravity model (http://www.ngs.noaa.gov/TOOLS/Navdgrav/navdgrav.html) and the hydraulic corrector model.



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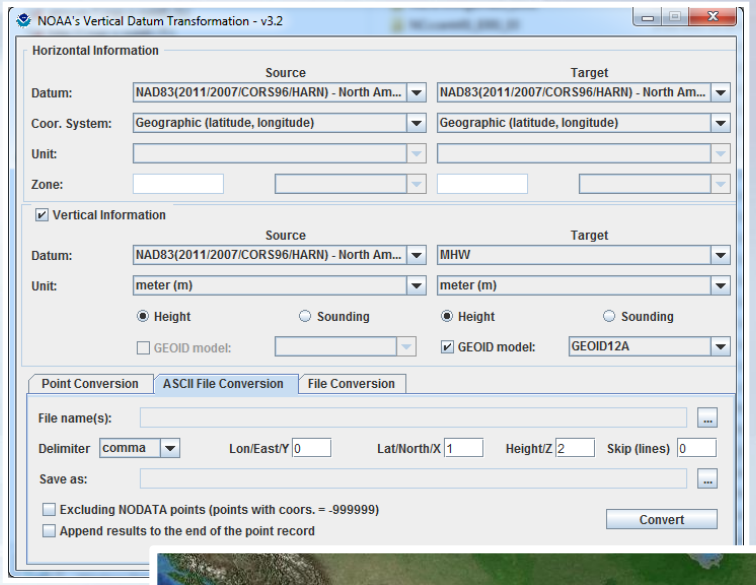
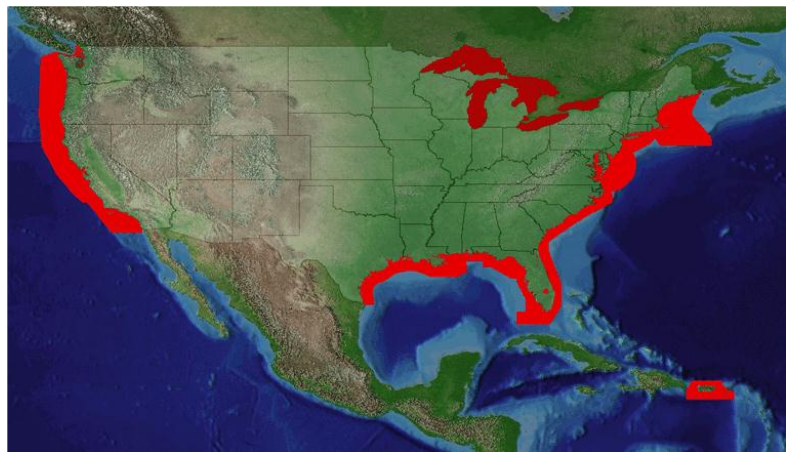
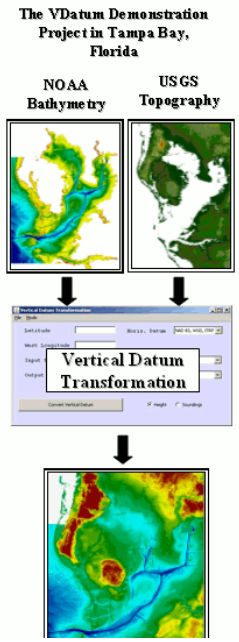
VDatum Website: vdatum.noaa.gov

(Version 3.2 Released March 21, 2013)







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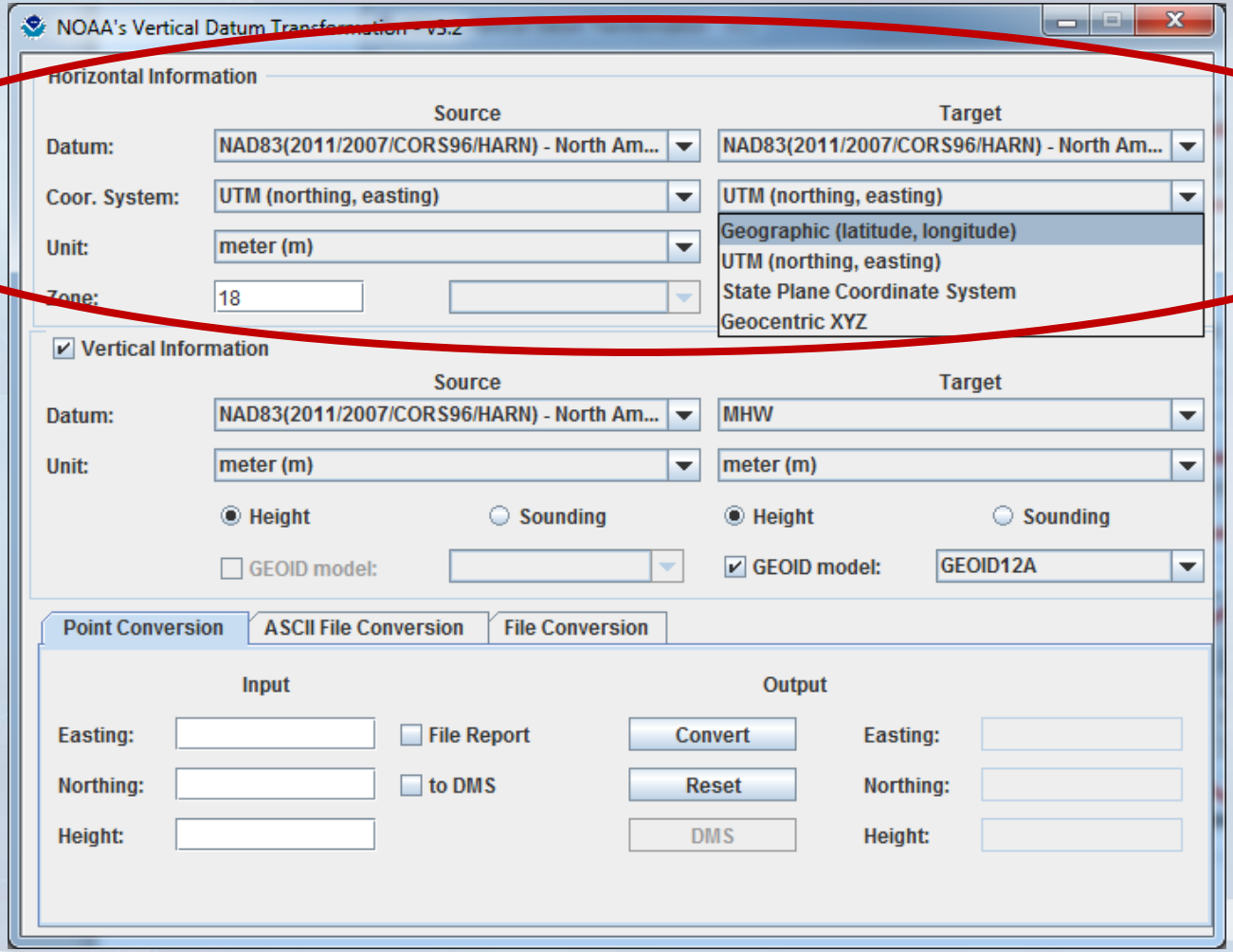
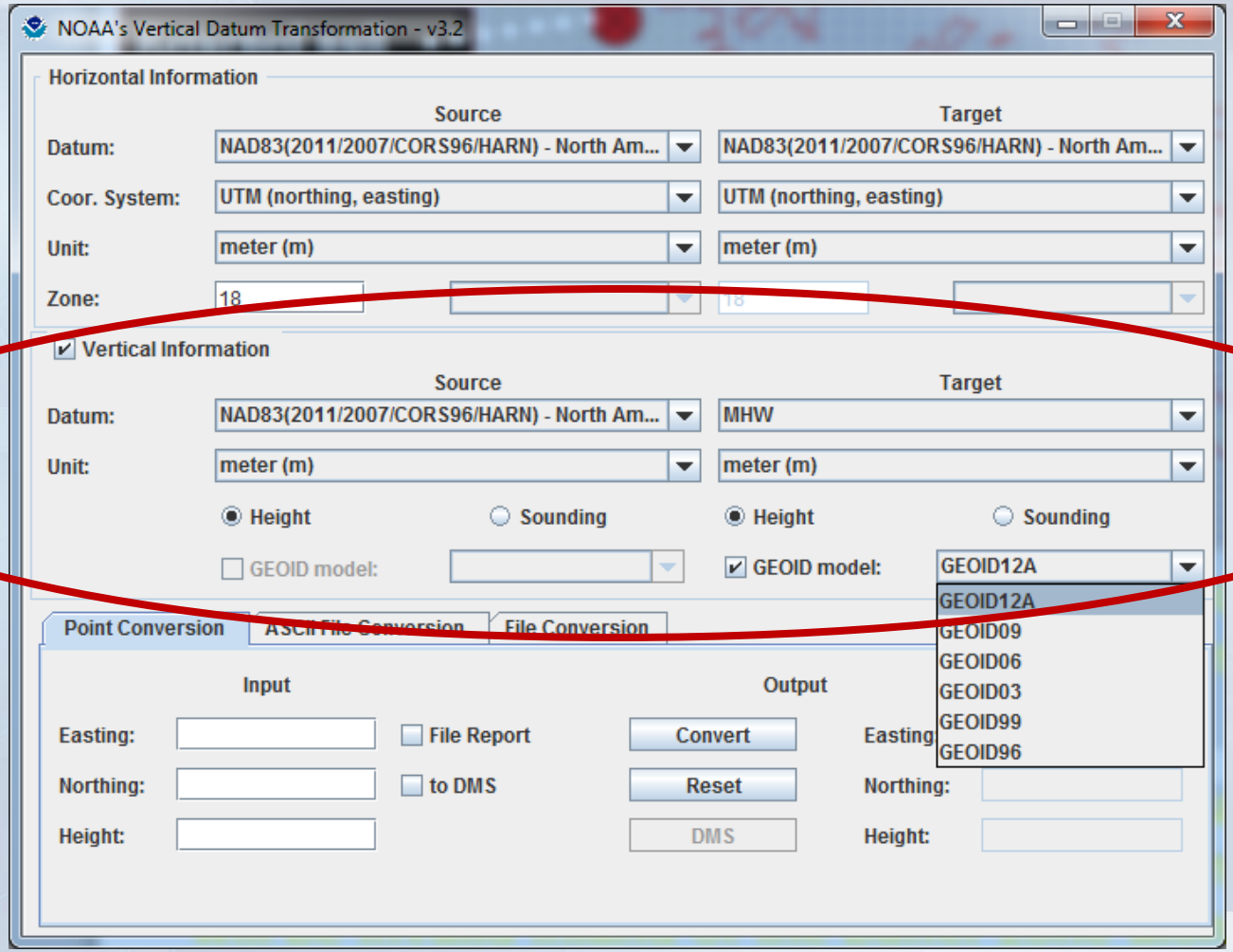
Utilizing VDatum: Horizontal



National Oceanic and Atmospheric Administration

Utilizing VDatum: Vertical



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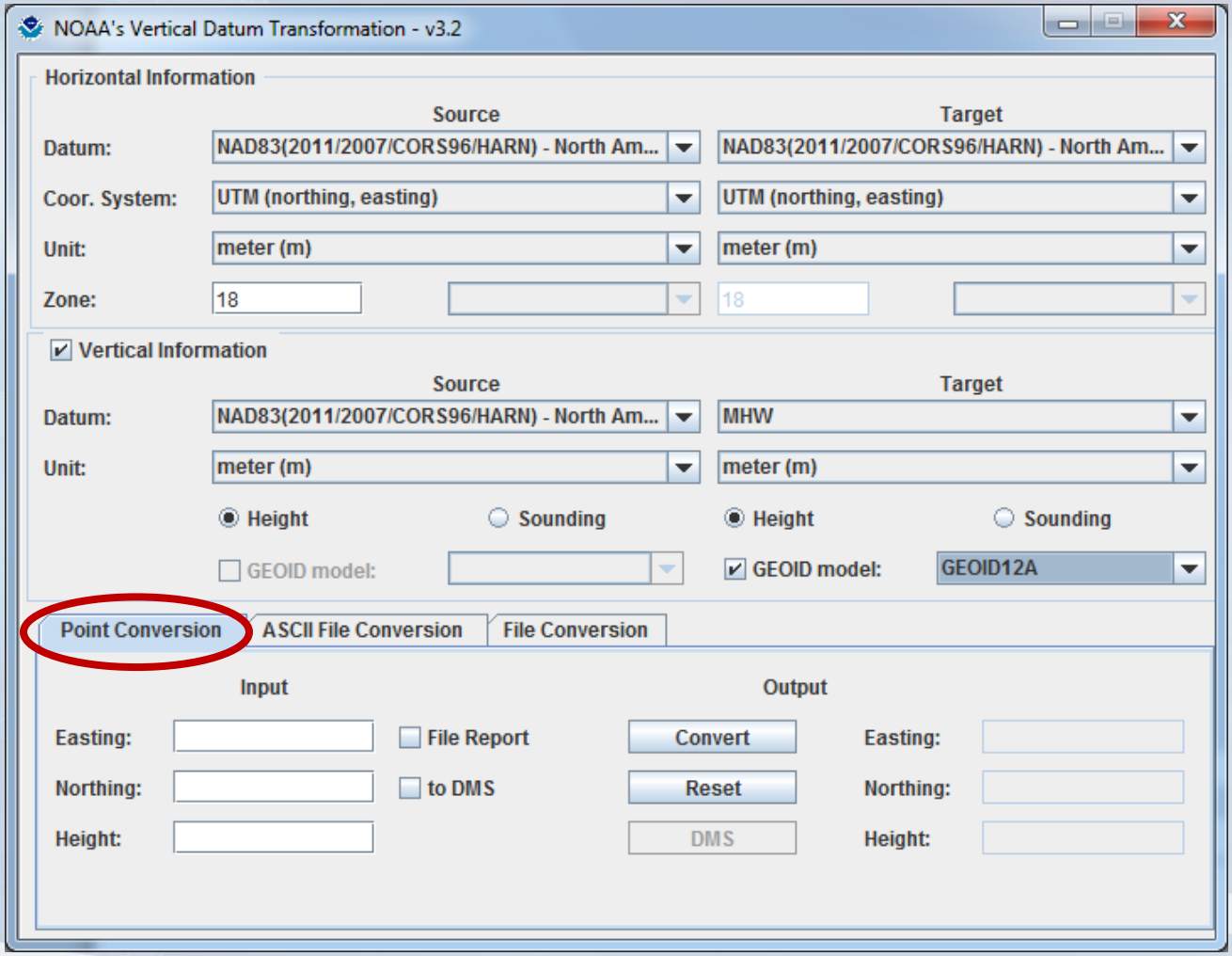
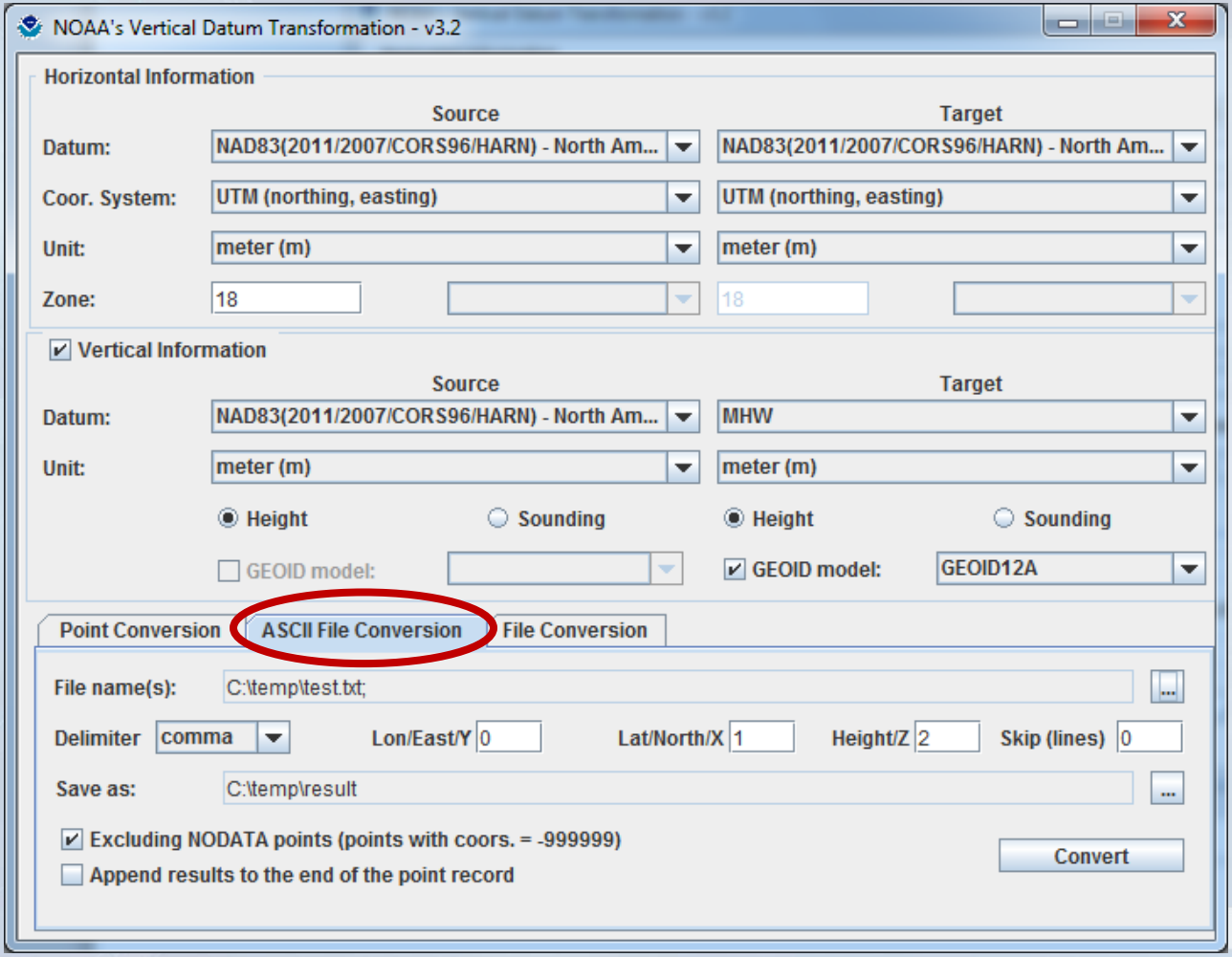
Utilizing VDatum: Input



National Oceanic and Atmospheric Administration

Utilizing VDatum: Input



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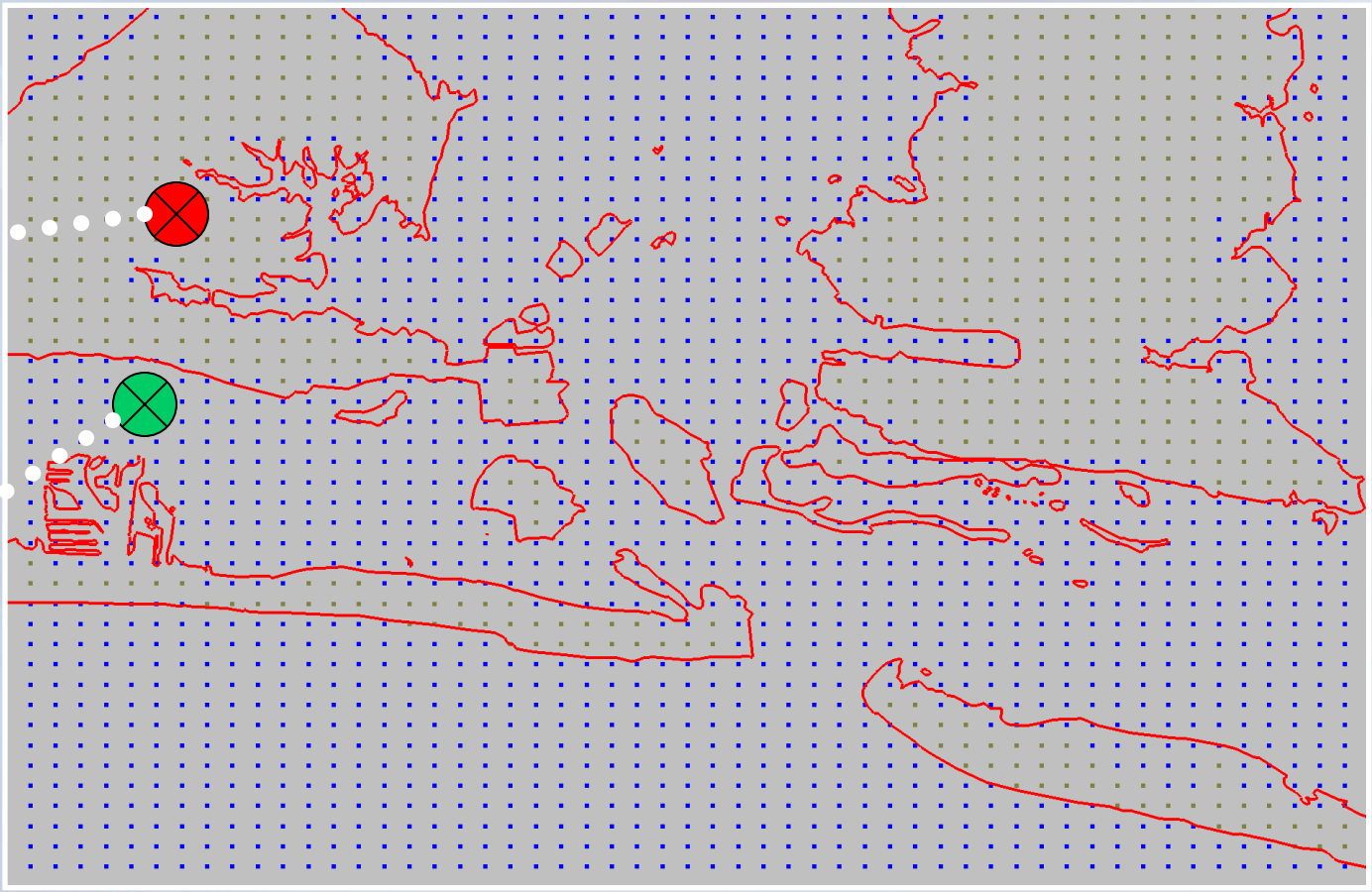
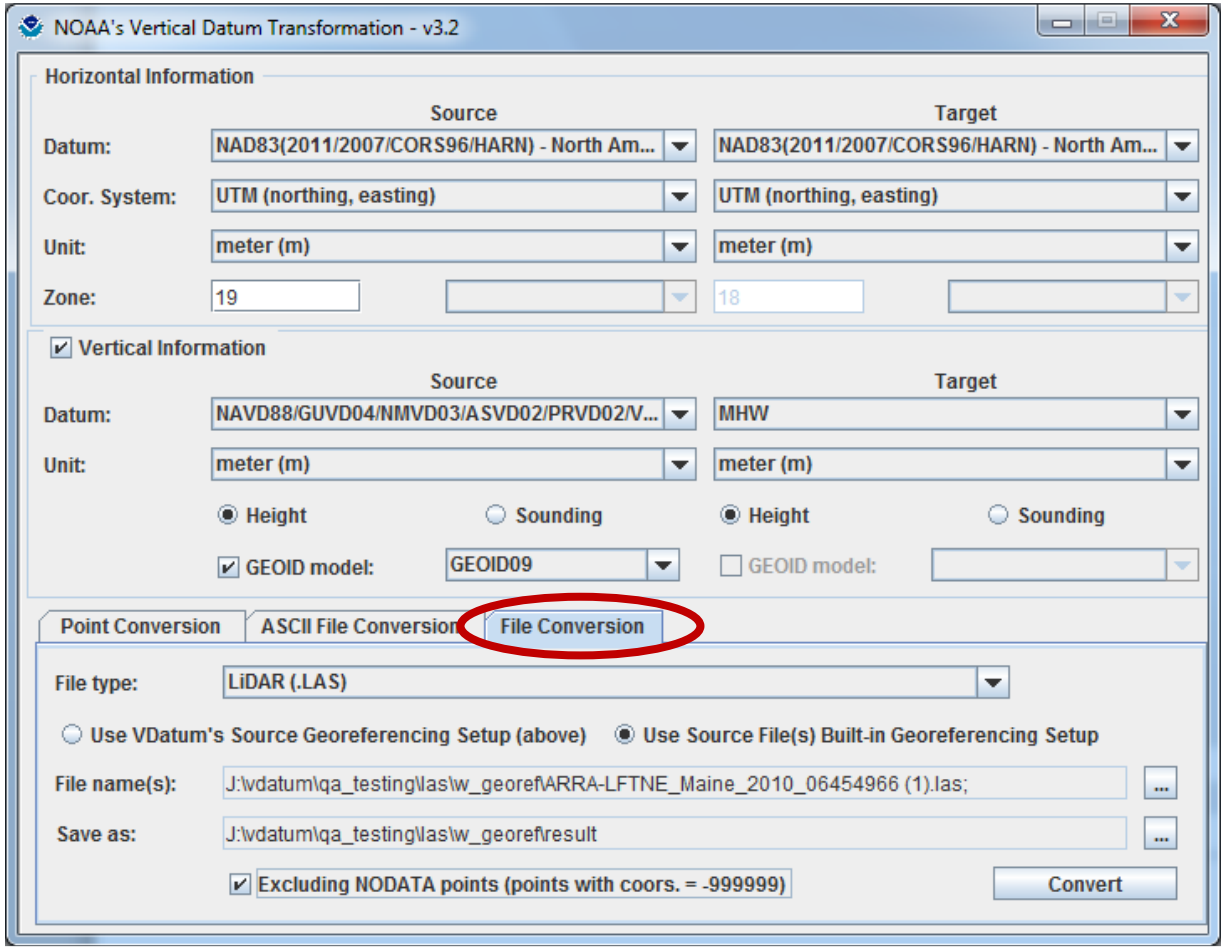
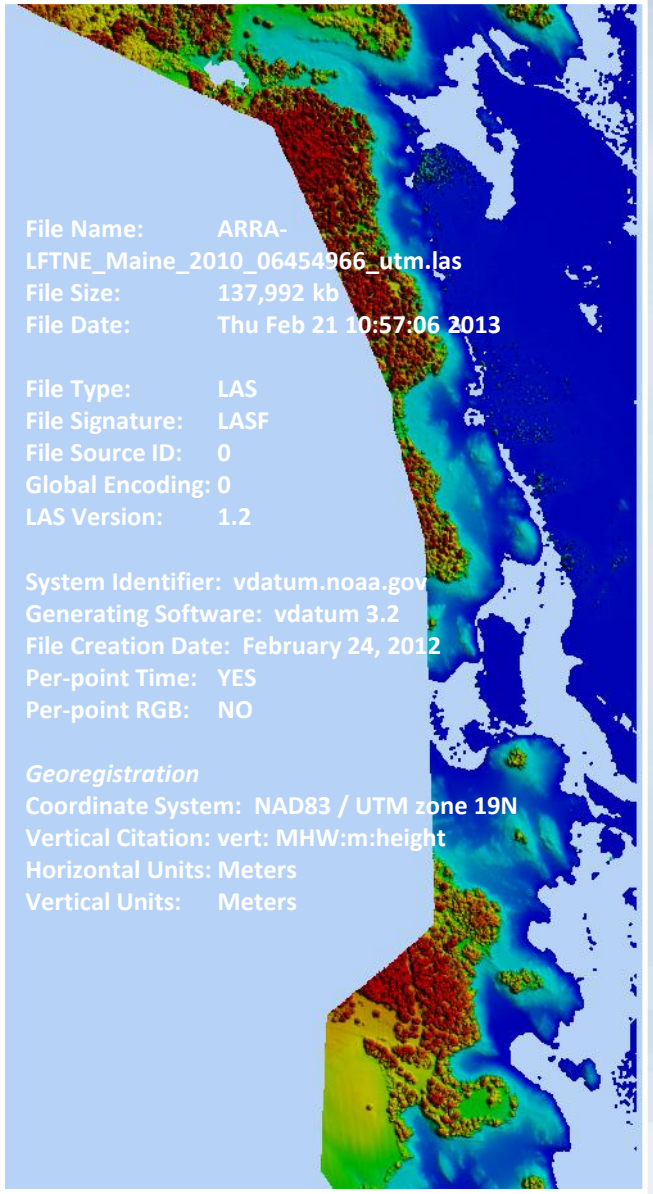


- With exception of small buffer region near coastline, user-input points falling on “land” side of MHW shoreline are assigned a null value.
- Orthometric and ellipsoidal conversions may still be made at land points, as only conversions involving tidal datums will be invalid inland of the buffer zone along coastline.

Utilizing VDatum: Input

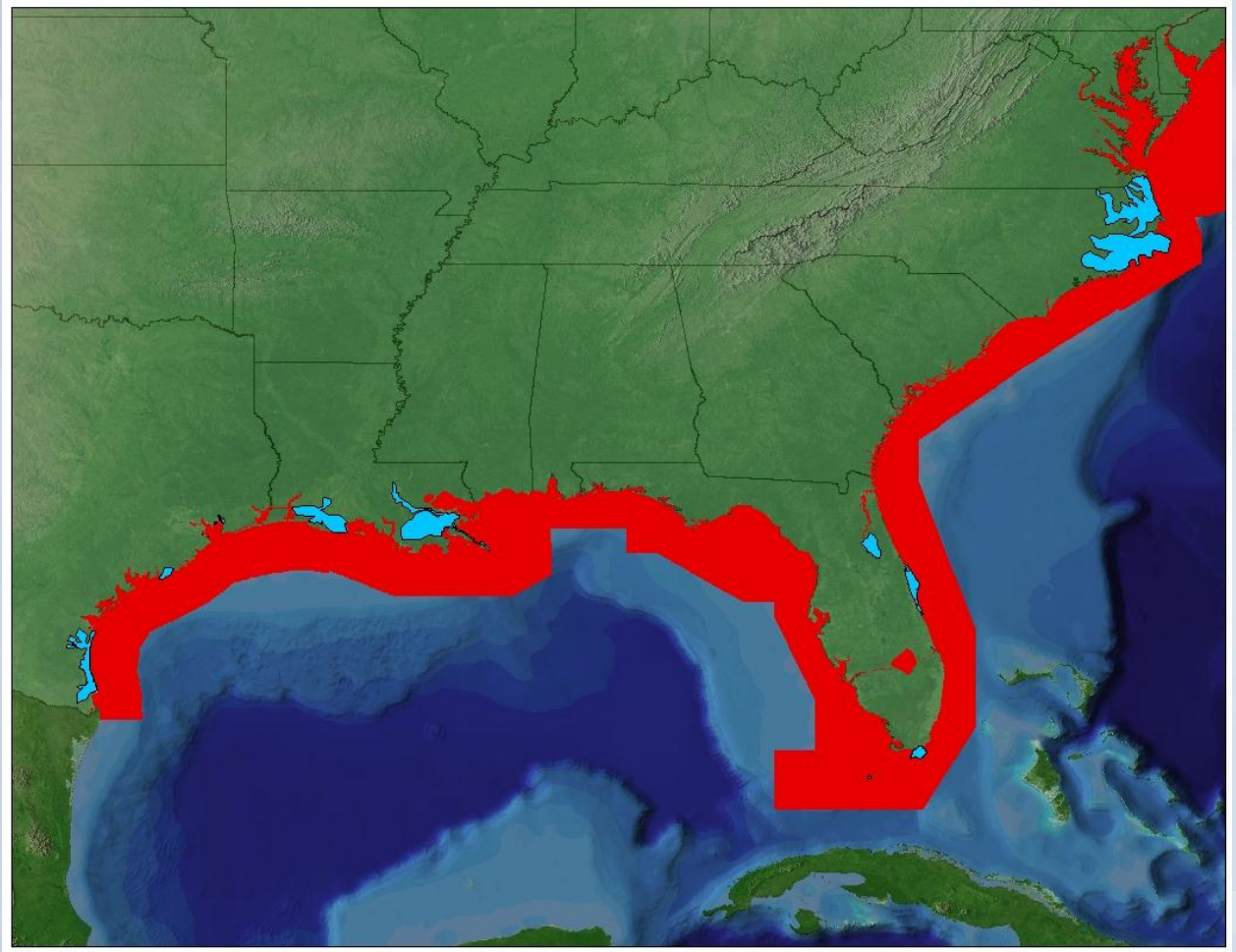




National Oceanic and Atmospheric Administration

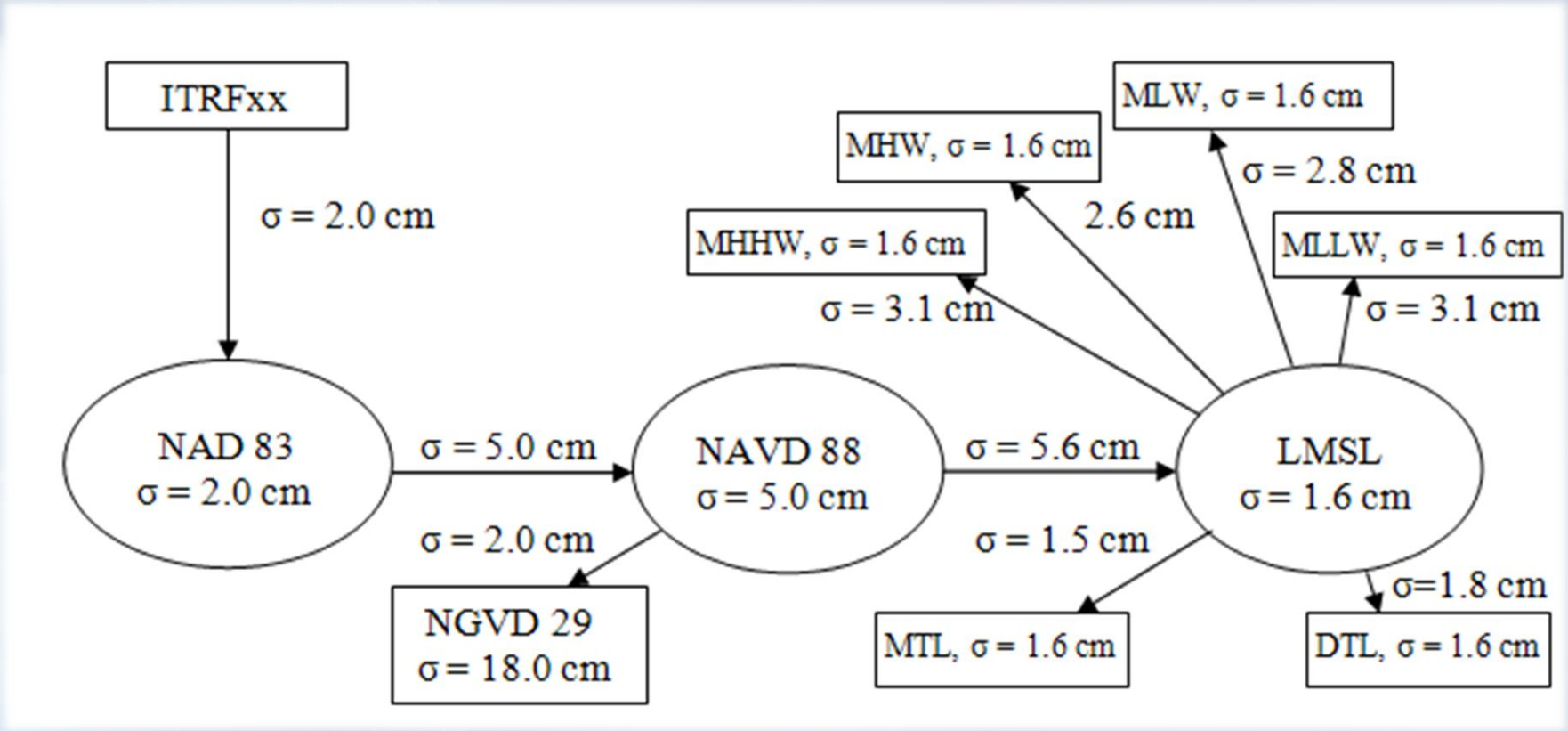
Software Updates:

- Auto detection of tidal areas
- Support for Low Water Datum (LWD) transformation in non-tidal areas
- Updated GEOID model support (96-12A)



National Oceanic and Atmospheric Administration

VDatum Uncertainty Modeling



See: vdatum.noaa.gov/docs/est_uncertainties.html

VDatum Uncertainty Modeling (cm)

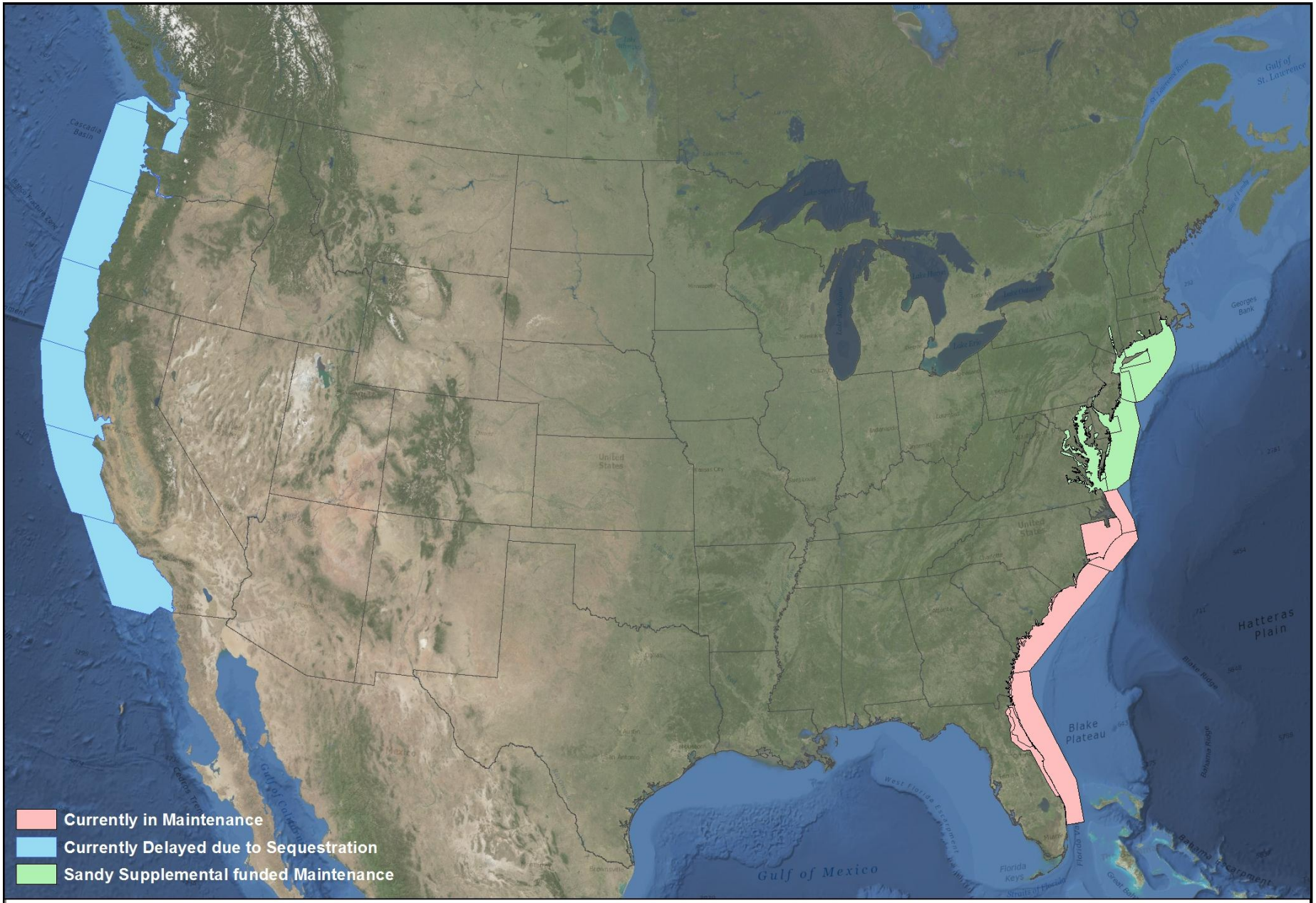
(ITRFxx to the tidal datum, the transformation with the greatest uncertainty)

VDATUM REGION	MAXIMUM CUMULATIVE UNCERTAINTY
California - Southern California from Morro Bay south to US/Mexico border	8.1
California - Monterey Bay to Morro Bay	8.0
California - San Francisco Bay Vicinity	9.8
Oregon/ California – Punta Gorda to Cape Blanco	13.1

Uncertainties that are constant for all VDatum regions of the U.S.

TRANSFORMATION			SOURCE DATA		
ITRFx to NAD83	NAD83 to NAVD88	NAVD88 to NGVD29	NAD83	NAVD88	NGVD29
2.0	5.0	2.0	2.0	5.0	18.0

REGION	TRANSFORMATION							SOURCE DATA	MCU
	NAVD88 to MSL	MSL to MHHW	MSL to MHW	MSL to MTL	MSL to DTL	MSL to MLW	MSL to MLLW	All Tidal Datums	
California - Southern California from Morro Bay south to US/Mexico border	1.6	1.4	0.9	0.1	0.4	0.8	0.9	1.3	8.1
California - Monterey Bay to Morro Bay	1.1	0.8	1	0.7	1	0.9	1.7	1.1	8
California - San Francisco Bay Vicinity	0.1	3.7	4.5	2	2.5	4.2	5.8	1.4	9.8
Oregon/ California – Punta Gorda to Cape Blanco	4.4	2	1.6	2.5	4.4	5.7	9.5	1.2	13.1

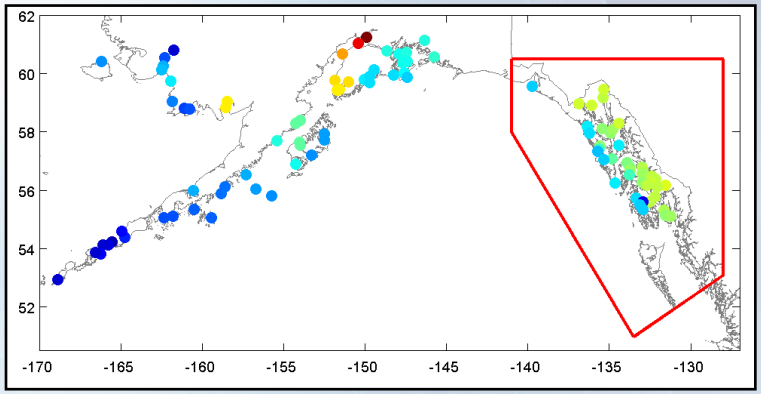


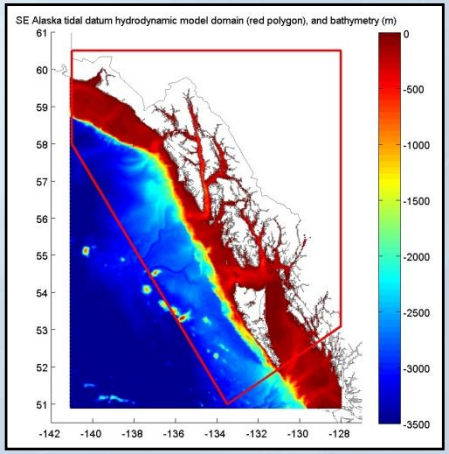
VDatum Production and Maintenance Schedule

Exploratory Alaska Tidal Modeling

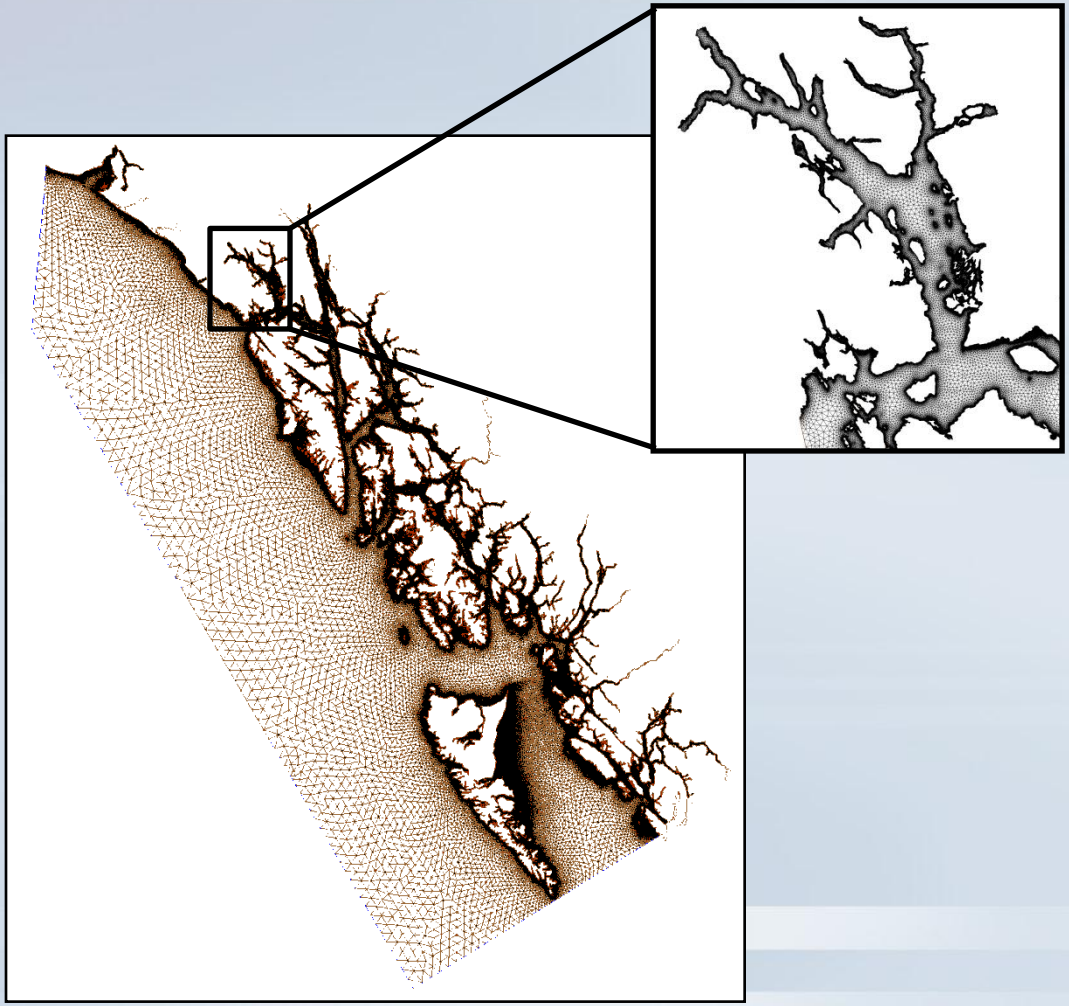
Southeast Alaska

Model Domain, Shoreline, and Tidal Data (M_2 amplitude shown in color)





Bathymetry



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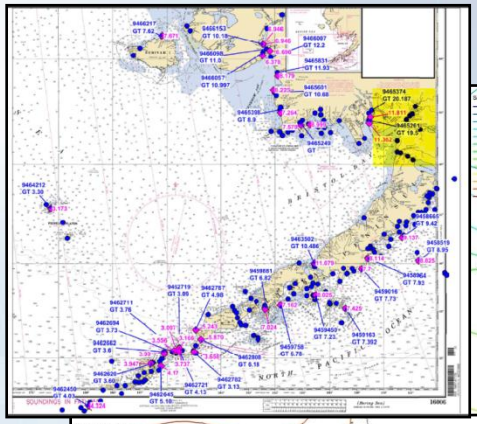
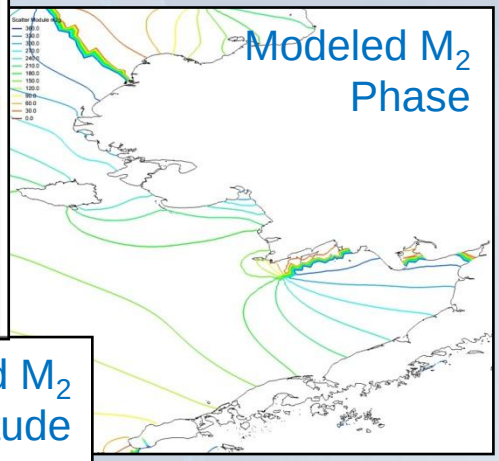
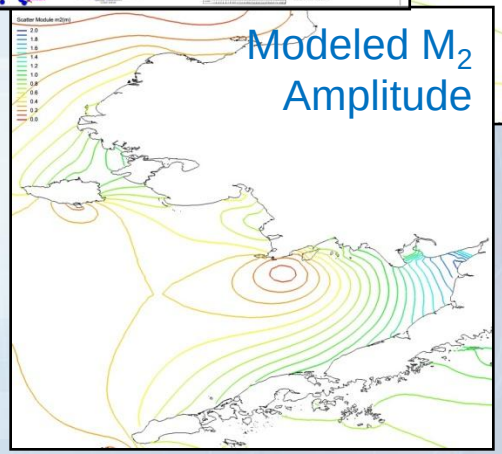
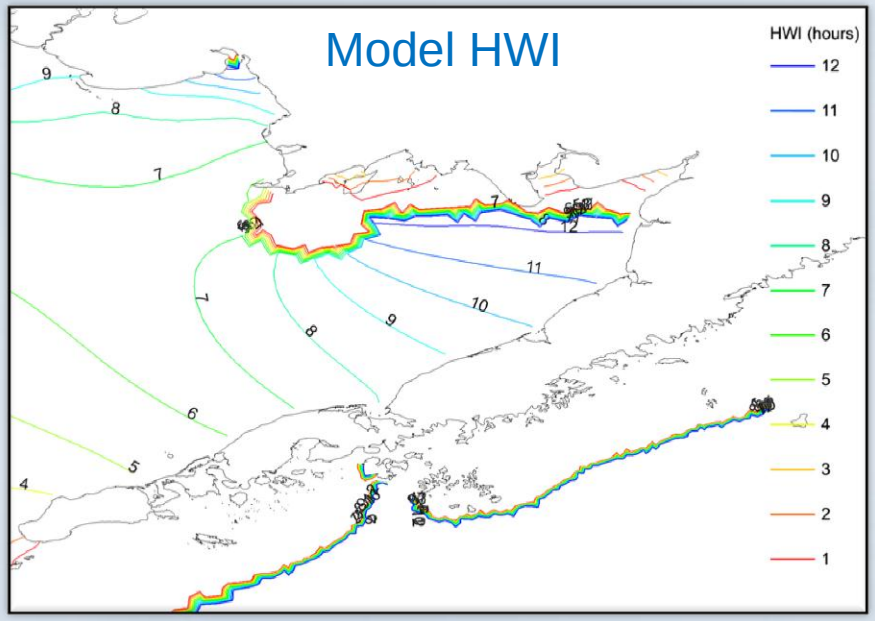
Exploratory Alaska Tidal Modeling

Western Alaska



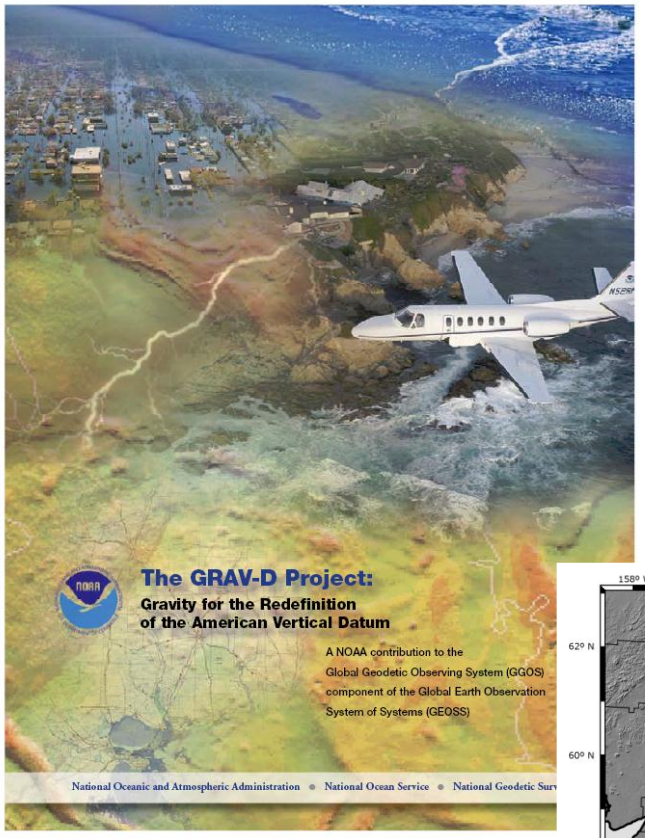




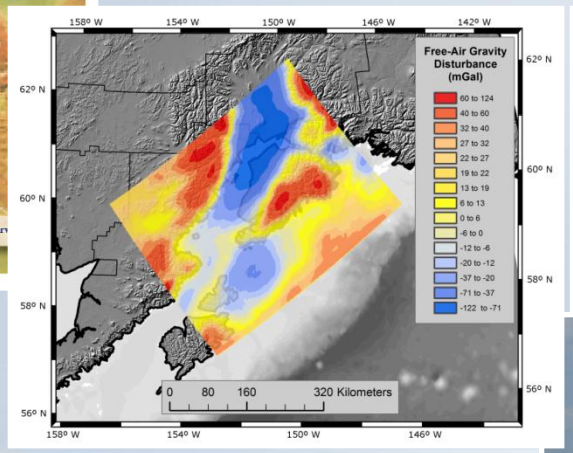


National Oceanic and Atmospheric Administration

GRAV-D: (**G**ravity for the **R**edefinition of the **A**merican* **V**ertical **D**atum)



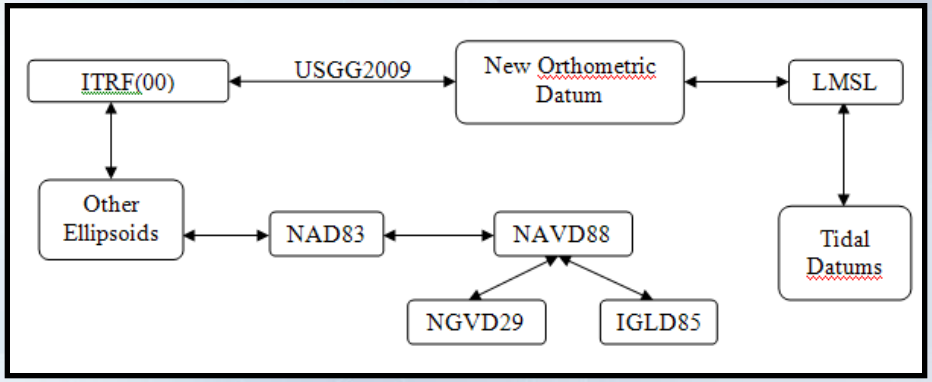
- An NGS project whose target is to redefine the official civilian vertical datum as the geoid, realized through the use of GNSS technology and a gravimetric geoid model over at least the United States and its territories
- *Official NGS policy as of Nov 14, 2007*
- *Re-define the Vertical Datum of the USA by 2022 (at current funding levels)*
- *Part of the NGS 10 year plan (2013-2023)*
- *Target: 2 cm accuracy orthometric heights from GNSS and a geoid model*

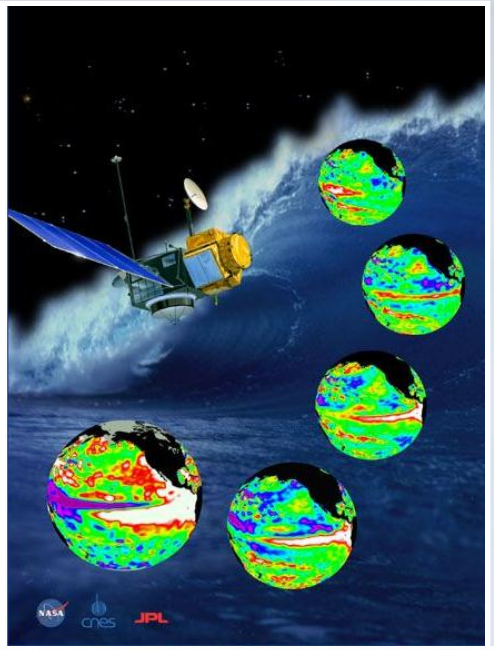


National Oceanic and Atmospheric Administration

Future Enhancements: Next Generation TSS Development

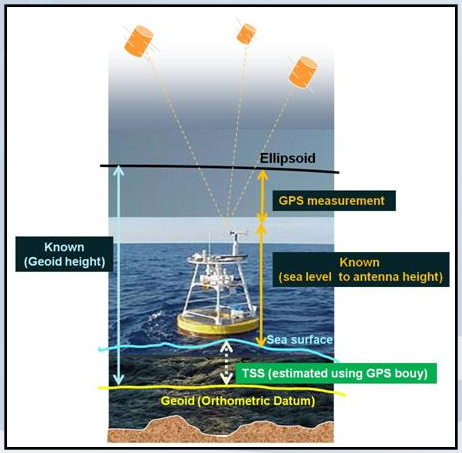
New Proposed Transformation Roadmap based on a purely Gravimetric GEOID

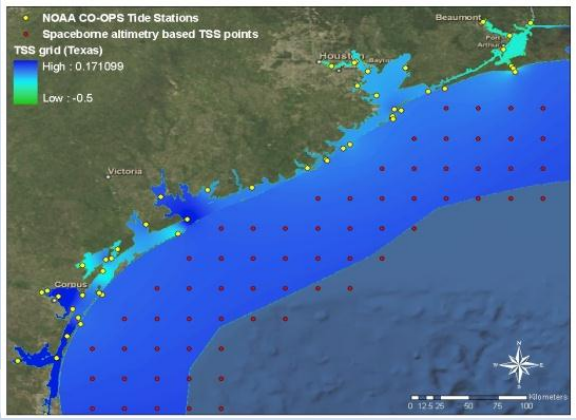




A Must: GPS Campaign on benchmarks to determine new relationships

Wish List: GPS tide buoys to be utilized for data input, validation, and calibration inshore and offshore

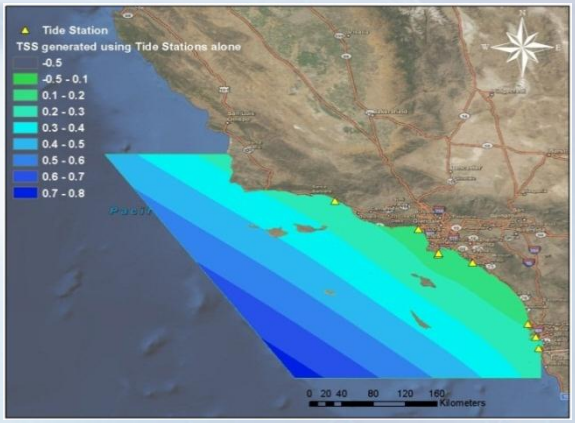




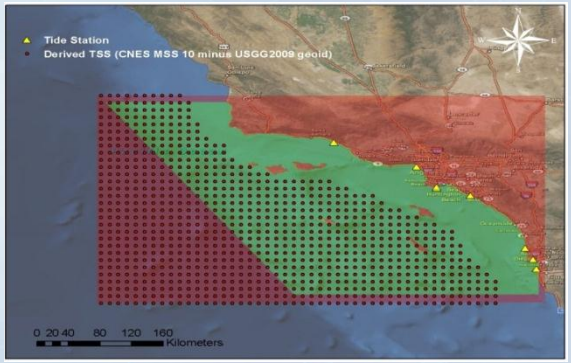
Utilization of Satellite Altimetry/Derived Products to better understand offshore Sea Surface Topography

National Oceanic and Atmospheric Administration

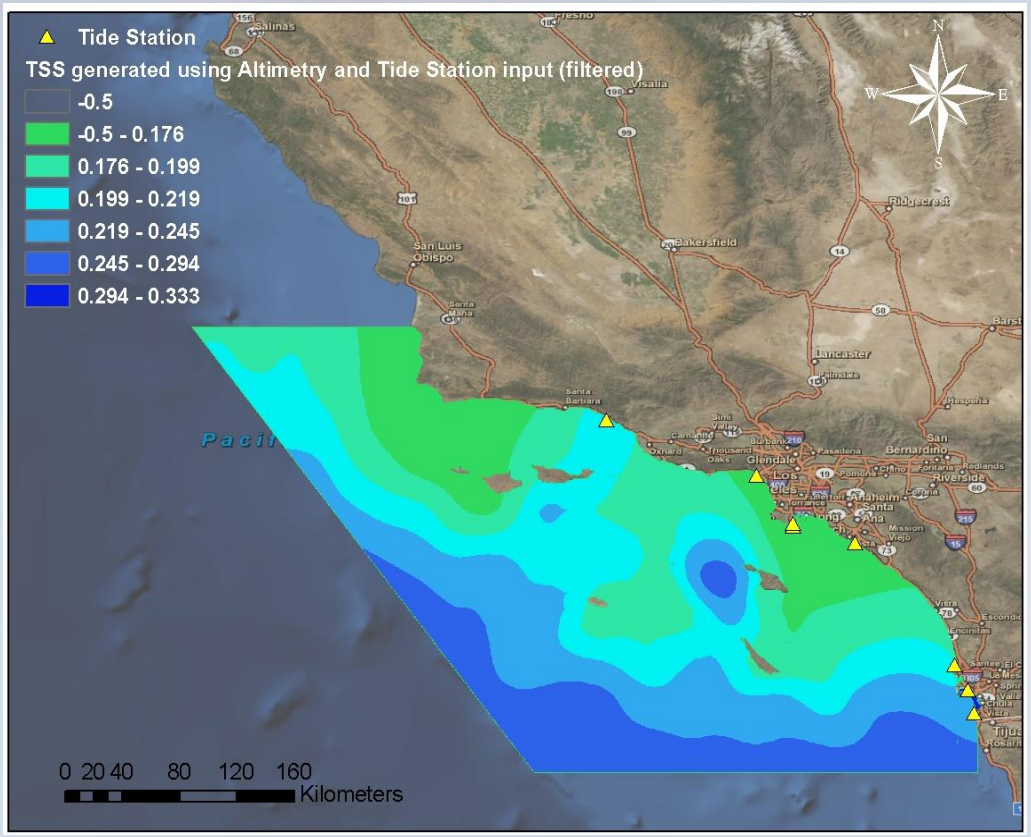
Future Enhancements: Next Generation TSS Development



TSS generated with only the 8 tide stations



TSS points derived at the location of tide stations (yellow triangle) and CNES MSS points (red dots). These TSS points are the input for TSS grid (0.001 degree spacing) creation.

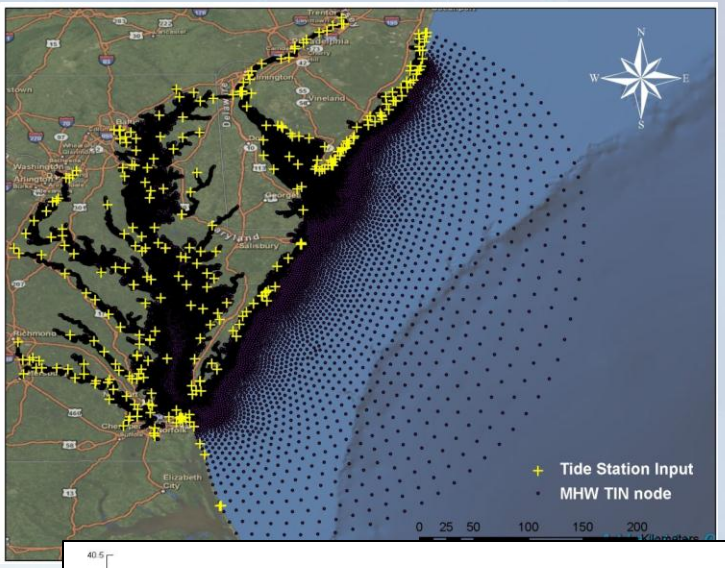


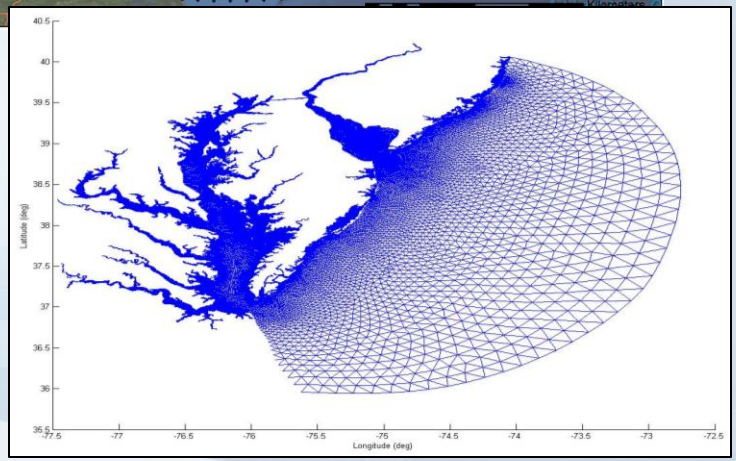
Refined TSS grid created using the derived TSS points at CNES MSS points (Gaussian filtered), and newly determined geodetic relationships at tide stations

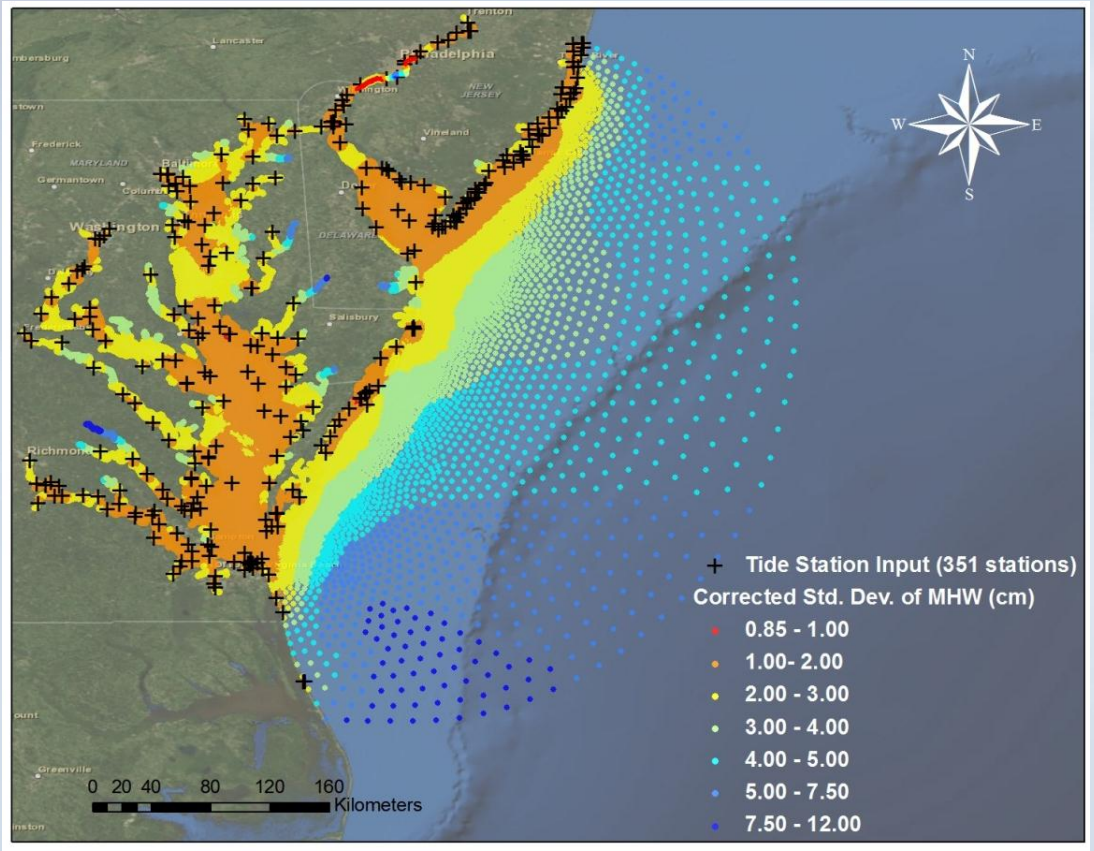
National Oceanic and Atmospheric Administration

Future Enhancements: Spatially Variable Uncertainty Estimation

- **Test Area:** Chesapeake Bay area and Delaware Bay area. 351 tide stations in this region







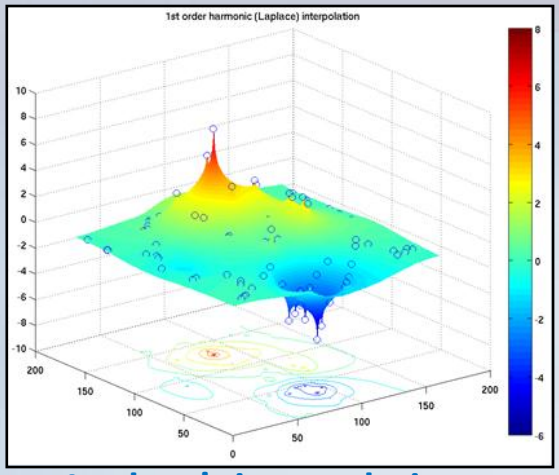
National Oceanic and Atmospheric Administration

Future Enhancements: Multiple-Order Harmonic Equation

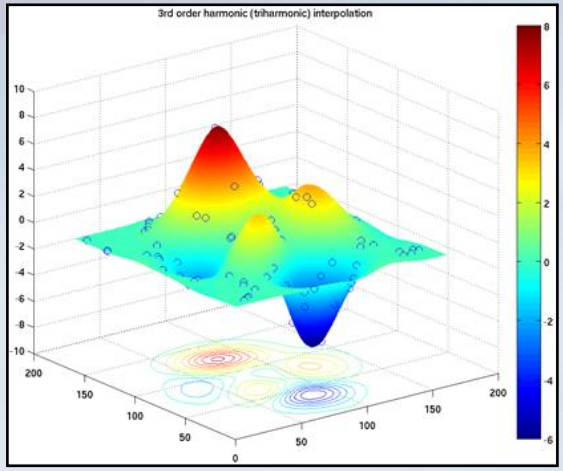
$$\sum_{k=1}^{K} \beta_k \Delta^k f = \sum_i F_i \delta(x - x_i, y - y_i)$$

$$\frac{\partial f}{\partial n} = \alpha(x, y) \frac{\overline{\partial f}}{\partial n}$$

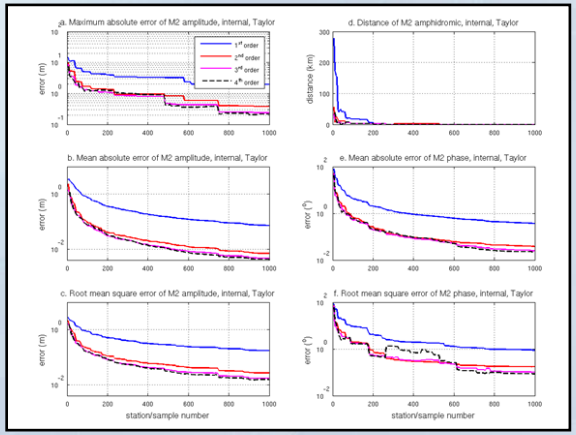
$$\frac{\partial \Delta^k f}{\partial n} = 0 \text{ , (k=1, 2, 3, …, K-1)}$$

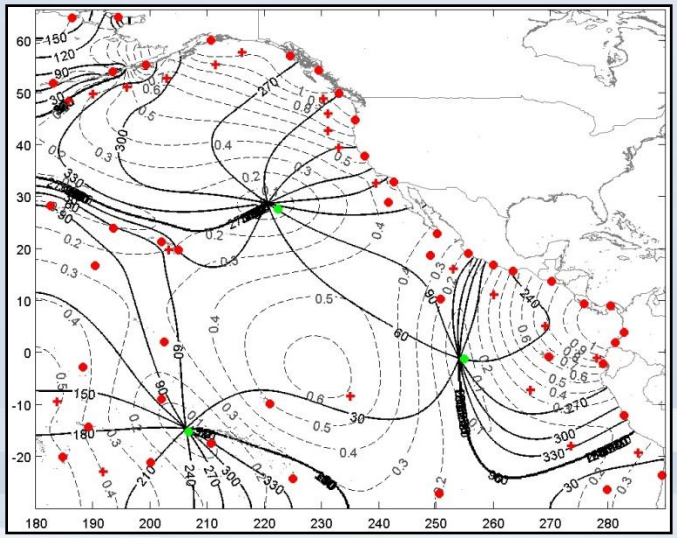


Laplace's interpolation



Triharmonic interpolation





National Oceanic and Atmospheric Administration

Future Enhancements: VDatum GIS Format Support

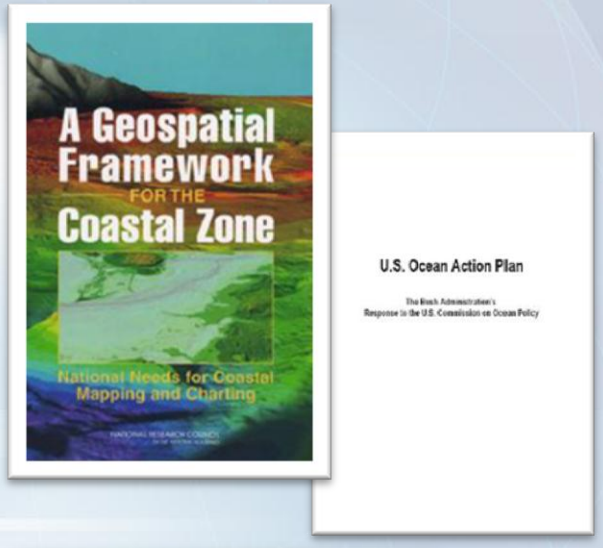
- **Feasibility Report:** Identify potential GIS data formats that VDatum could support.
- **Current Formats:** single point, ASCII input file, and LAS files.
- **Proposed Formats and Tools:**

Format	Data Model	Tool	Source
Shapefile	Vector	Reader and Writer	In-house
ESRI ASCII Grid	Raster	Reader and Writer	Explore Third-party tools
KML	Vector	Reader and Writer	In-house
TIFF	Raster	Reader and Writer	Explore Third-party tools

VDatum Applications

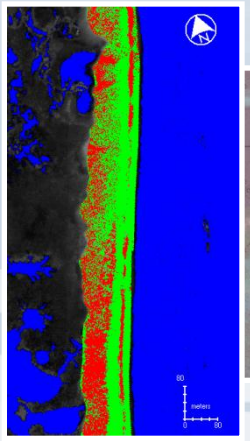
National Oceanic and Atmospheric Administration

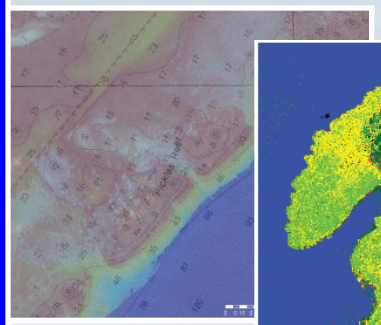
Integrated Ocean and Coastal Mapping (IOCM)

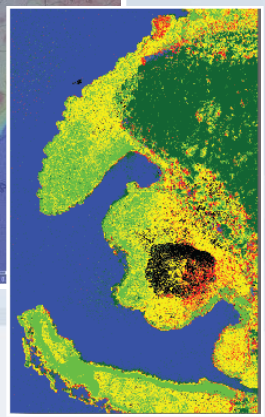


The practice of acquiring, managing, integrating and disseminating ocean and coastal geospatial mapping data in such a manner that permits these data and their derivative products to be easily accessed and used by and for the greatest range of users and purposes.

IOCM requires intra- and inter-agency coordination with a focus on streamlining operations, reducing redundancies, improving efficiencies, developing common standards, and stimulating innovation and technological development.



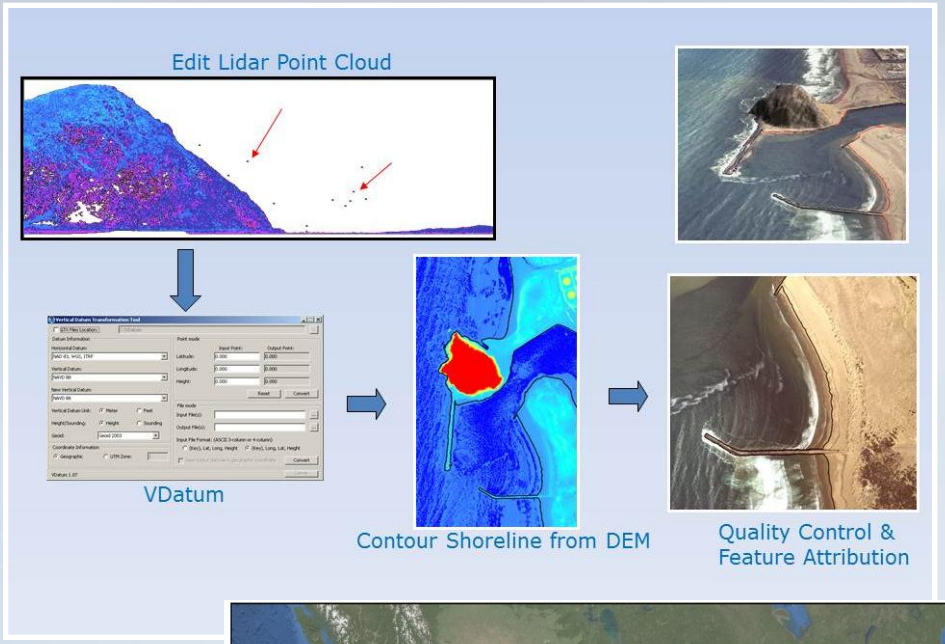


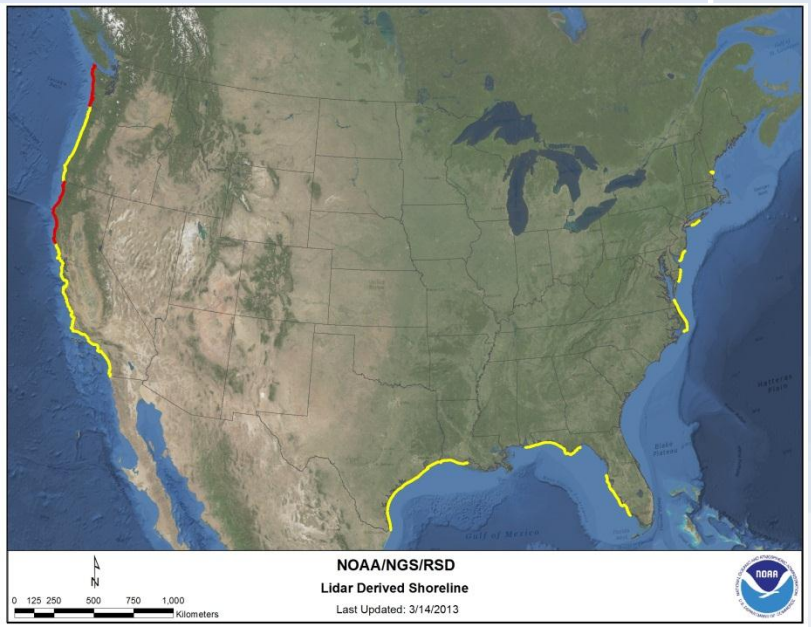


National Oceanic and Atmospheric Administration

Shoreline Extraction: A VDatum Charting Application

- Supports delineating the National Shoreline.
- Assist in Providing the Nation With Accurate, Consistent, Up-to-Date Shoreline.
- Is utilized in defining the United States' territorial limits.
- Important applications:
  - NOAA nautical charting
  - Coastal resource management
  - Storm surge and coastal flooding modeling
  - GIS analysis
  - Coastal geomorphology studies
  - Many more…





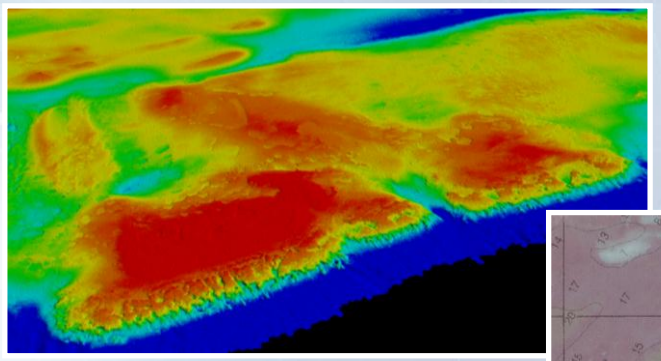
National Oceanic and Atmospheric Administration

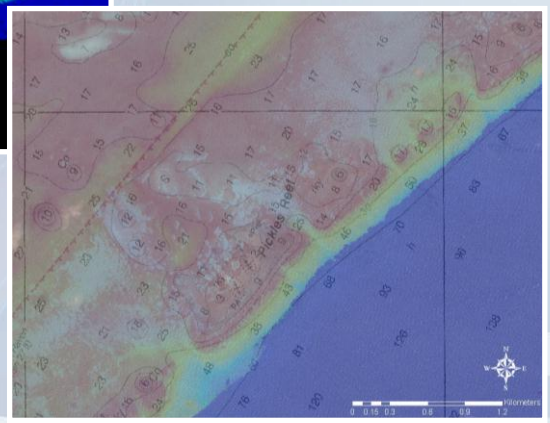
Surveying on the Ellipsoid:

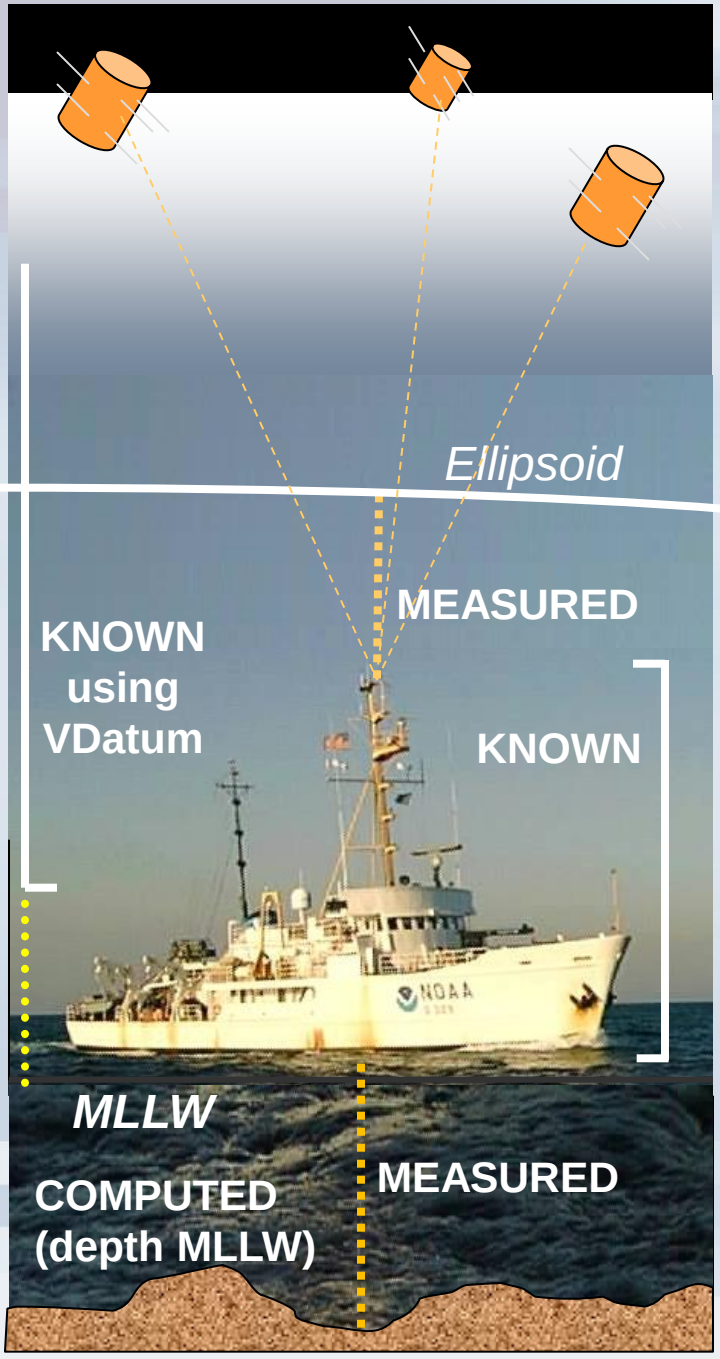
A VDatum Charting Application

Advantages:

- Decouple tide measurement from survey
- Reduce vertical uncertainty from heave, dynamic draft

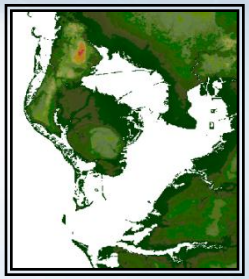




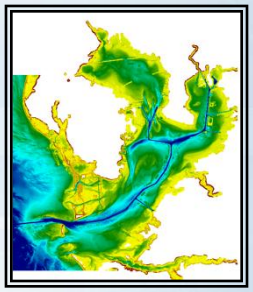


National Oceanic and Atmospheric Administration

VDatum: Used to Create Digital Elevation Models

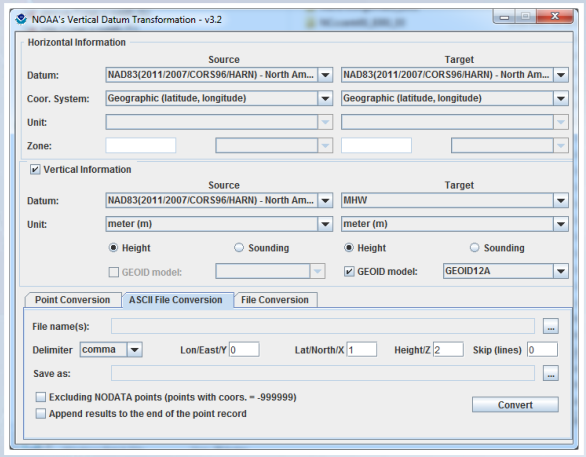


Topography

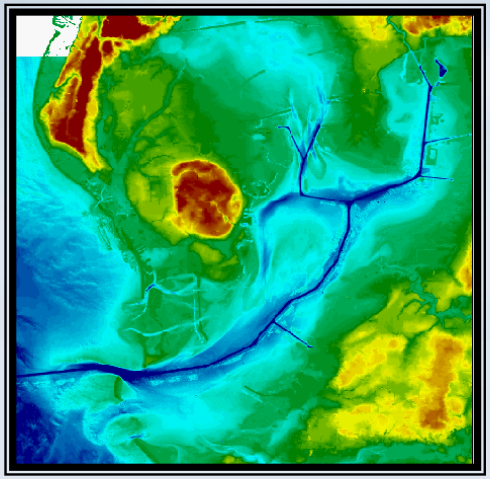


Bathymetry

VDatum



Topo/ Bathy Digital Elevation Model

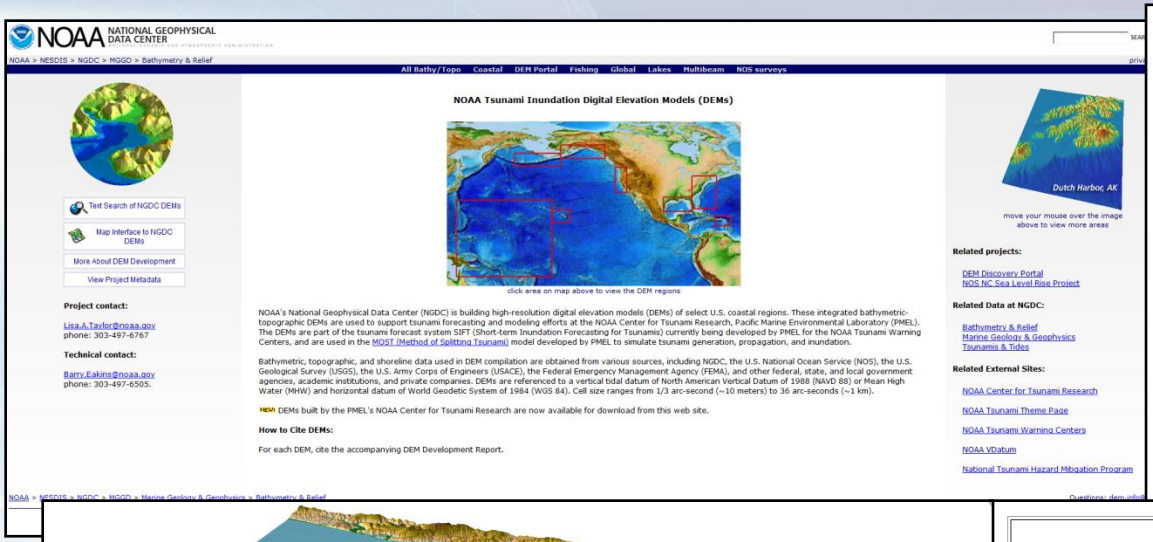


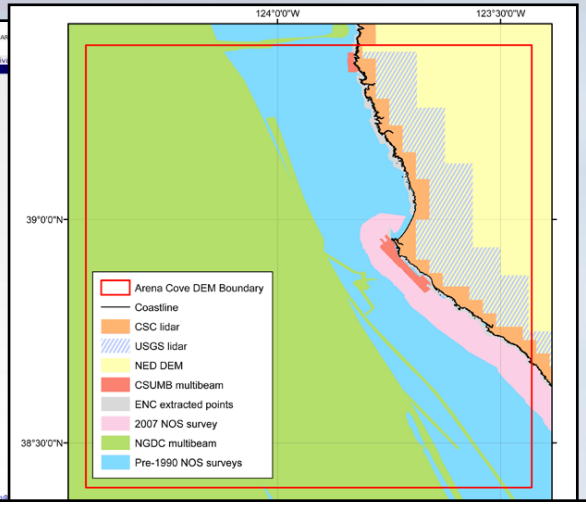
Applications for Seamless Bathy/Topo Datasets:

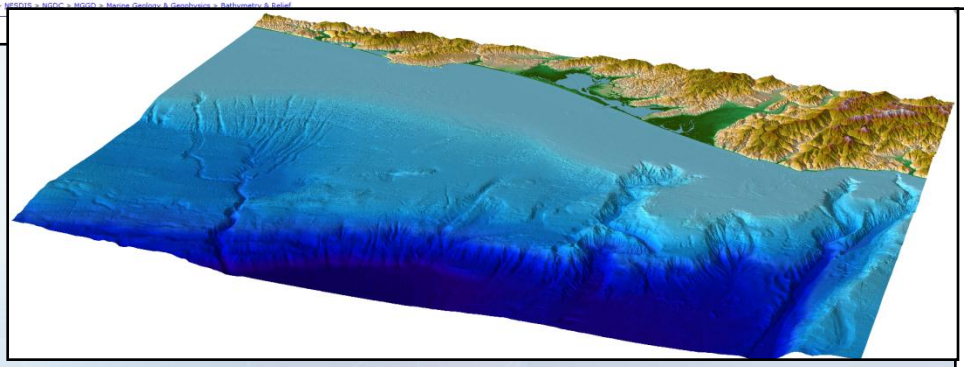
- Inundation modeling from storm surge, tsunamis, and sea level rise.
- Erosion, accretion, renourishment
- Analyzing storm impacts
- Determining setback lines
- Determining local, state, and national boundaries
- Navigation products and services
- Habitat restoration
- Shoreline Change Analysis
- Analyzing environmental and natural resources
- Permitting

National Oceanic and Atmospheric Administration

Utilizing VDatum for Digital Elevation Model Creation: Tsunami Inundation



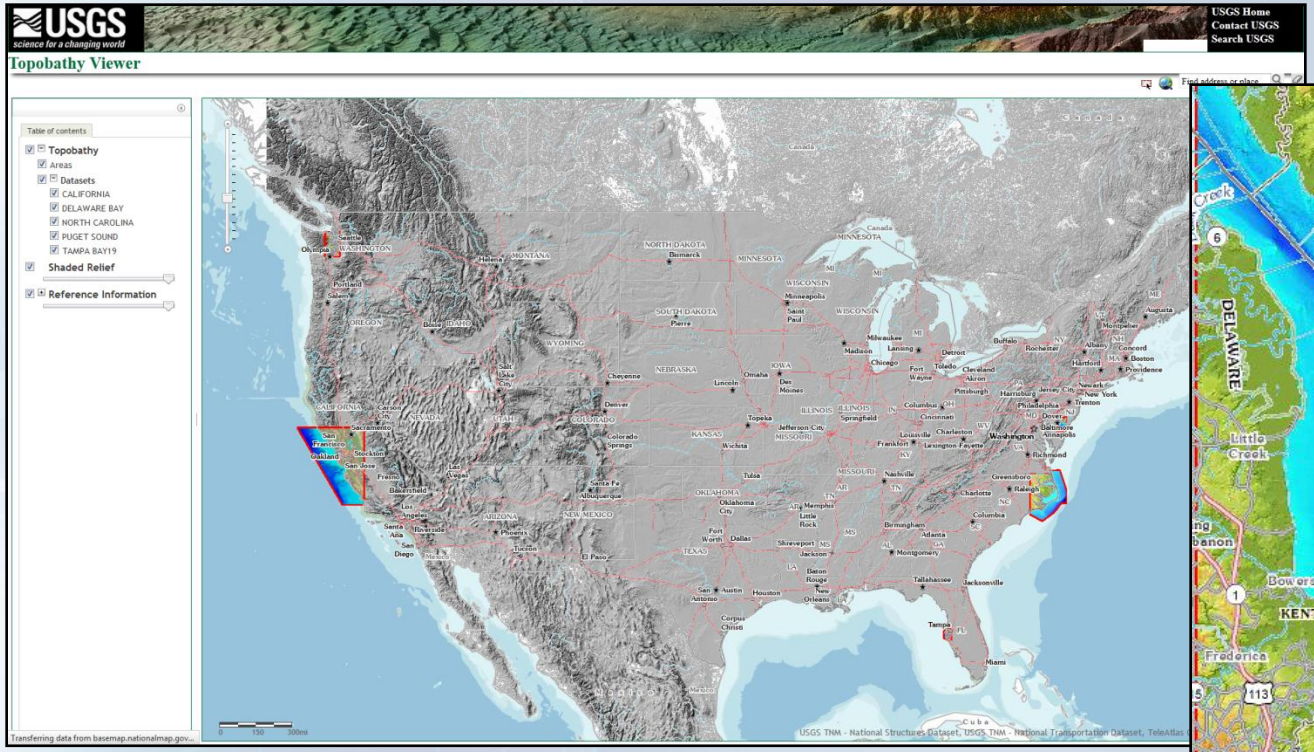


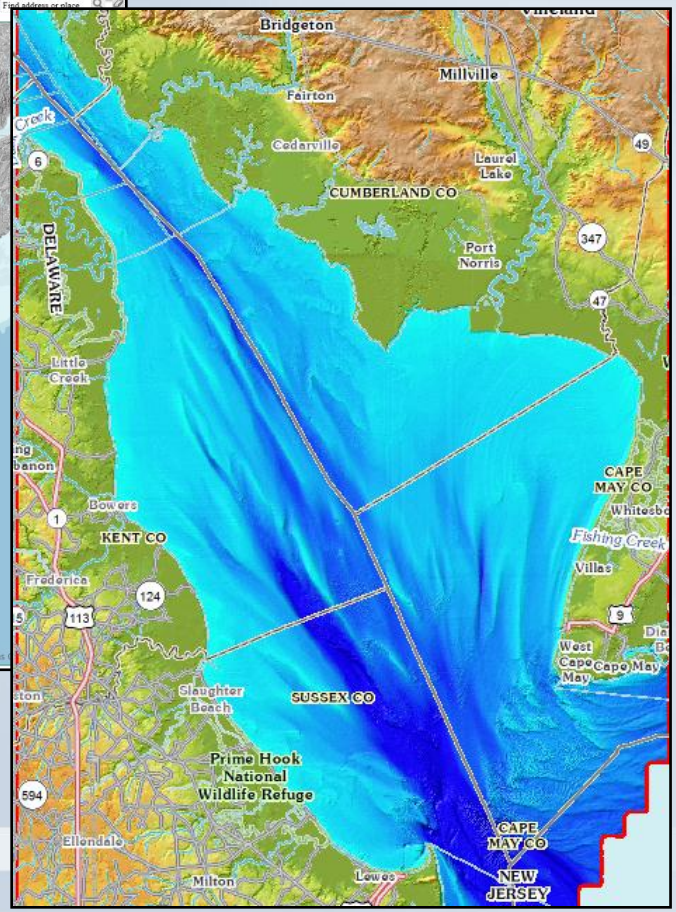


Source	Year	Data Type	Spatial Resolution	Original Horizontal Datum/Coordinate System	Original Vertical Datum
NGDC	1921 to 2008	NOS hydrographic survey soundings	Ranges from less than 10 m to 600 m (varies with scale of survey, depth, traffic, and probability of obstructions)	NAD 83 geographic	MLLW
NGDC	1984 to 2006	Multibeam swath sonar	gridded to 1 arc-second	WGS 84 geographic	Assumed Mean Sea Level
University of New Hampshire, Center for Coastal and Ocean Mapping, Joint Hydrographic Center	2009	Multibeam swath sonar	40 meter grid	WGS 84 geographic	Inferred Mean Sea Level
U.S. Army Corps of Engineers	2009	Hydrographic survey	Not Available	NAD 83 California State Plane I (feet)	MLLW
California State University Seafloor Mapping Laboratory	2005	Multibeam swath sonar	1 meter grid	WGS 84 UTM 10 North	NAVD 88
NOAA Office of Coast Survey	1992 to 2008	ENC extracted soundings	Not Available	WGS 84 geographic	MLLW

National Oceanic and Atmospheric Administration

Utilizing VDatum for Digital Elevation Model Creation

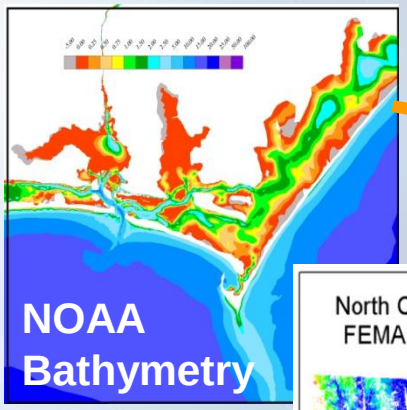


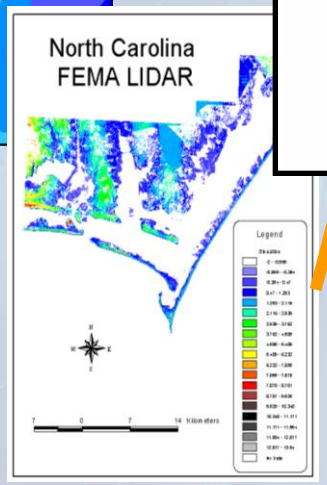


National Oceanic and Atmospheric Administration

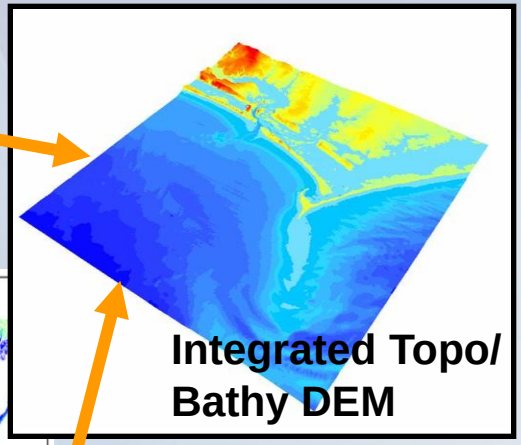
North Carolina Sea Level Rise Project

A VDatum application

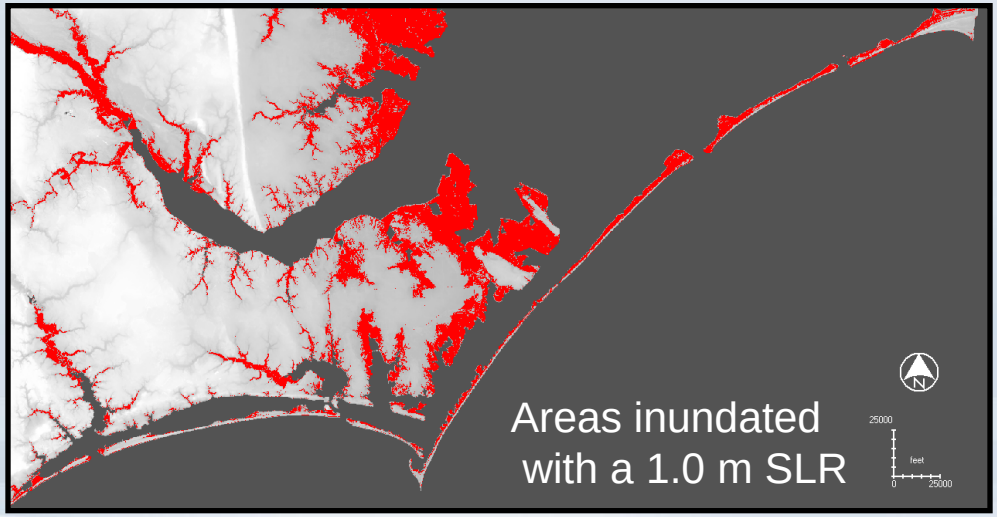




Land
Elevations

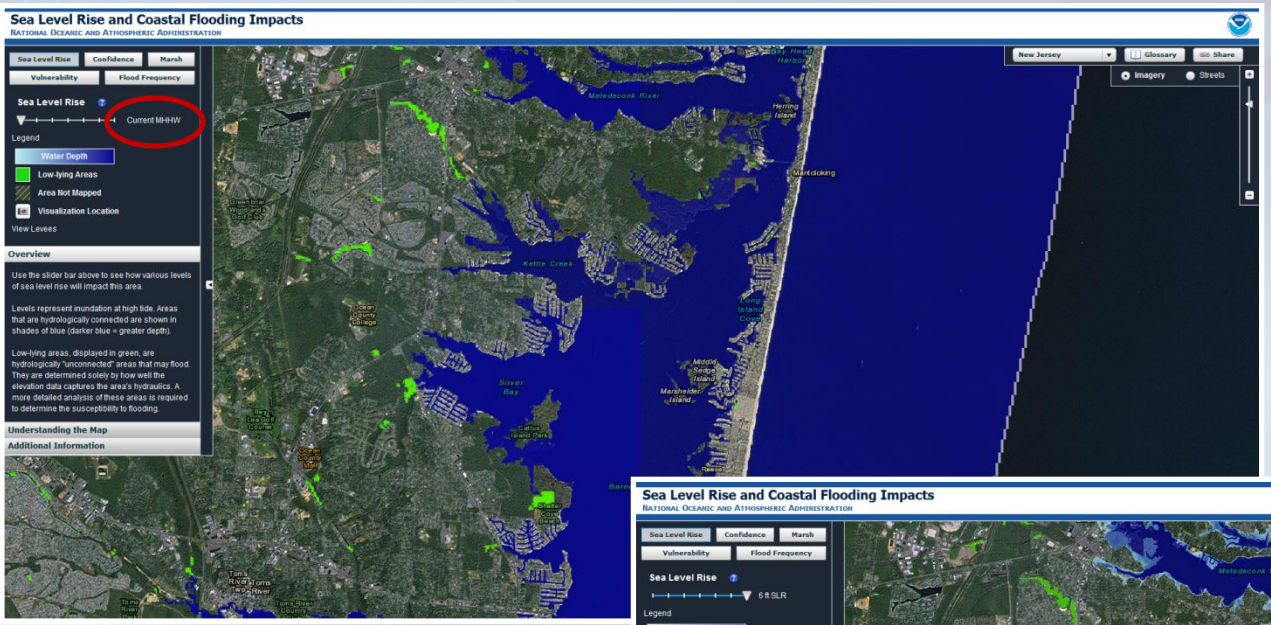


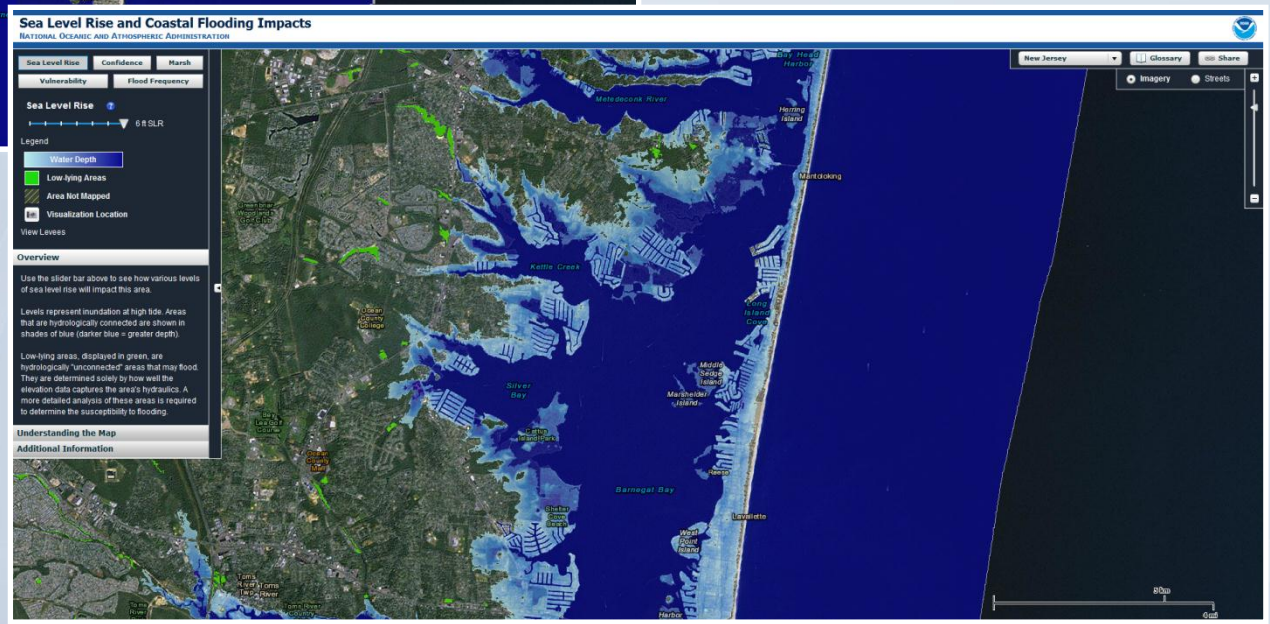
**Create a DEM
To assess
Sea Level Rise**



National Oceanic and Atmospheric Administration

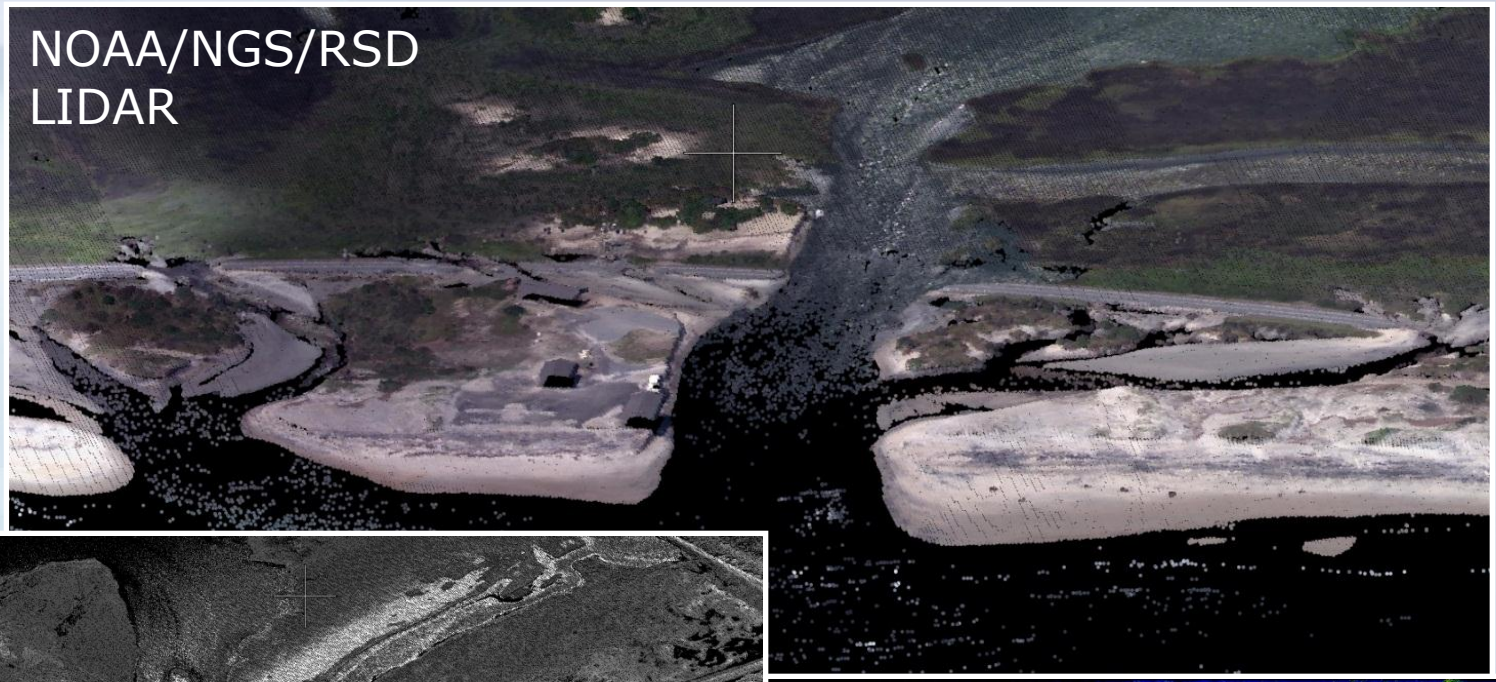
Sea Level Rise/Coastal Flooding

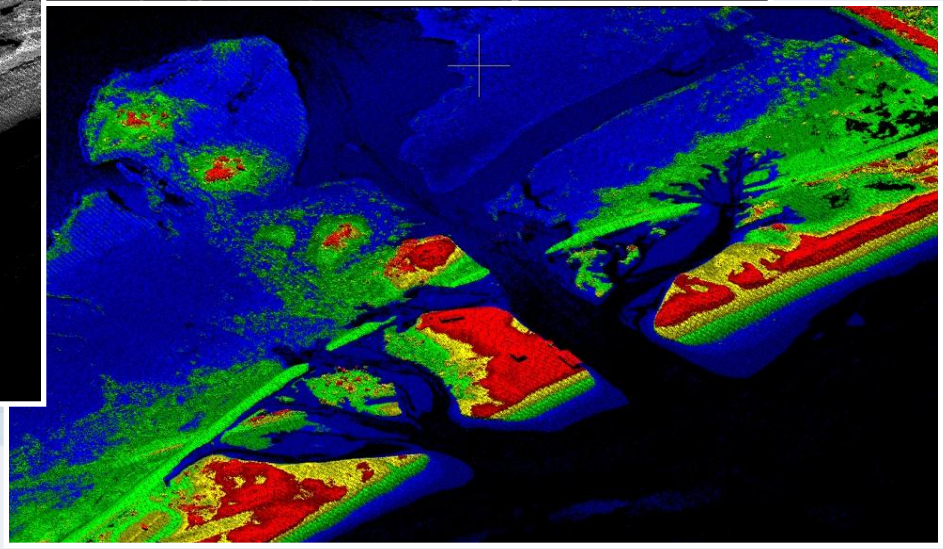




National Oceanic and Atmospheric Administration

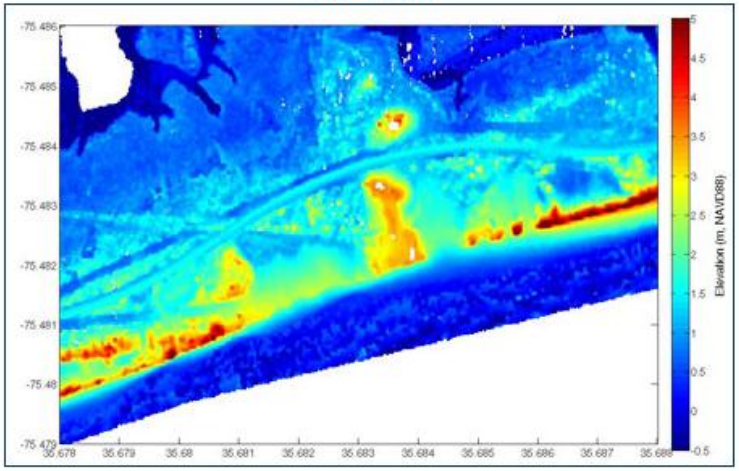
Emergency Response

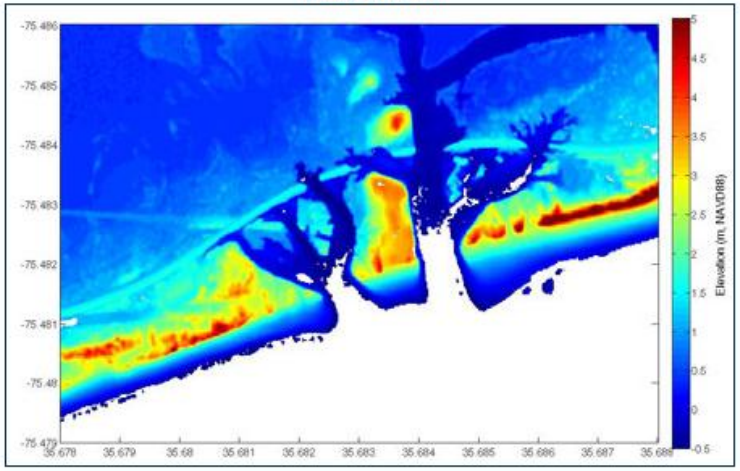


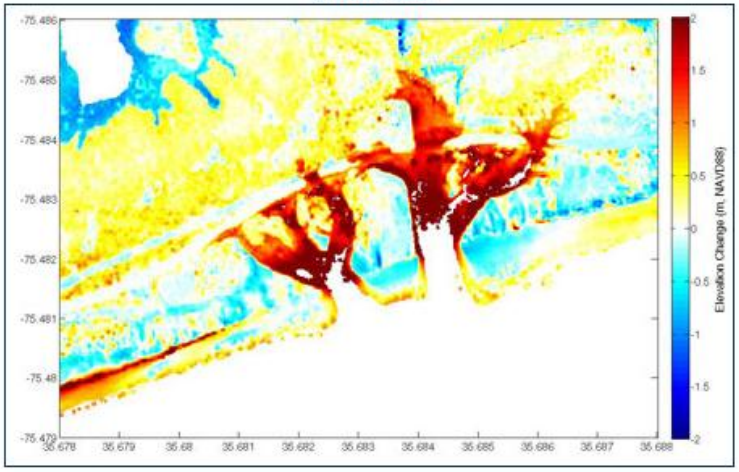


National Oceanic and Atmospheric Administration

Emergency Response







Location 5: Lidar topography from November 27-December 1, 2009 (Pre-Storm) and August 28-29, 2011 (Post-Storm) and topographic change (Difference) for a portion of the Outer Banks in the Pea Island National Wildlife Refuge, NC. In the pre-storm image, note the two particularly low elevation areas between a relative high. During the storm, surge and waves were funneled through the lower areas, carving two breaches (post-storm image). The difference image shows the intricate pattern of erosion associated with the formation of the breaches. See pre- and post-storm photo comparisons for additional discussion.

Courtesy of USGS

Thank You!

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