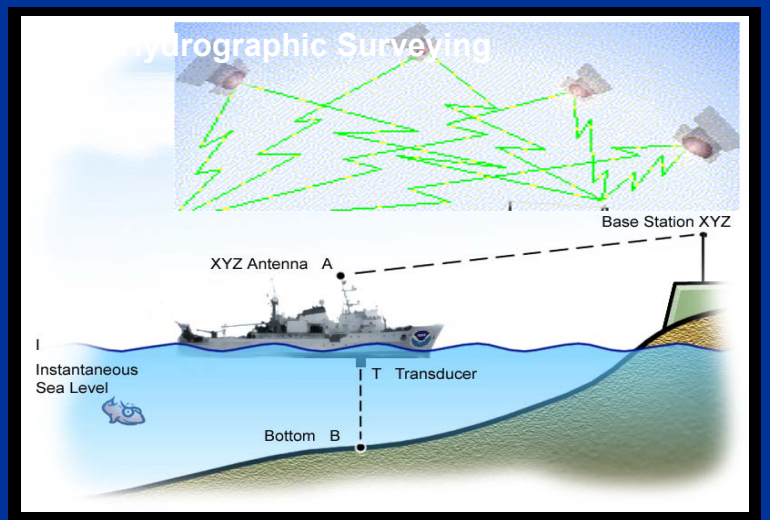
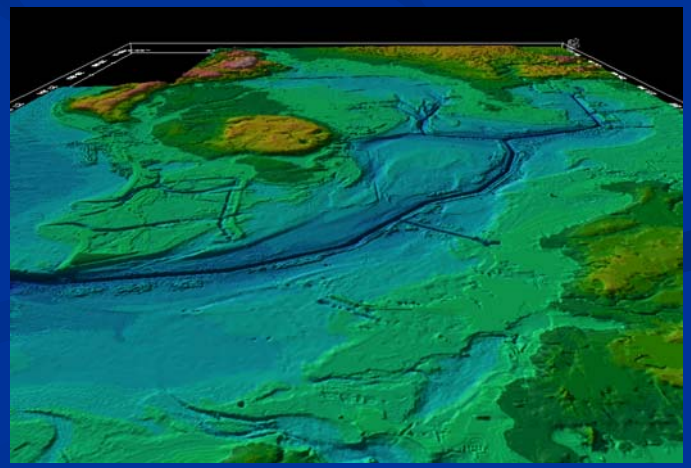
VIIIth IHO TC Meeting

Advances in Vertical Datum Transformation Tools and Use of Interpolation Tidal Models for Hydrographic Surveys at NOAA

Stephen Gill
NOAA, National Ocean Service
Center for Operational Oceanographic Products and Services





VIIIth IHO TC Meeting

Advances in Vertical Datum Transformation Tools and Use of Interpolation Tidal Models for Hydrographic Surveys at NOAA

- NOAA's Vertical Datum Transformation Tool - VDatum
- Tidal Constituent and Residual Interpolation Tool – TCARI
- Development of an web-based tidal prediction tool - eTides

All elevation data should be referenced to common vertical datums

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

Relationship of vertical datums for Tampa Bay:

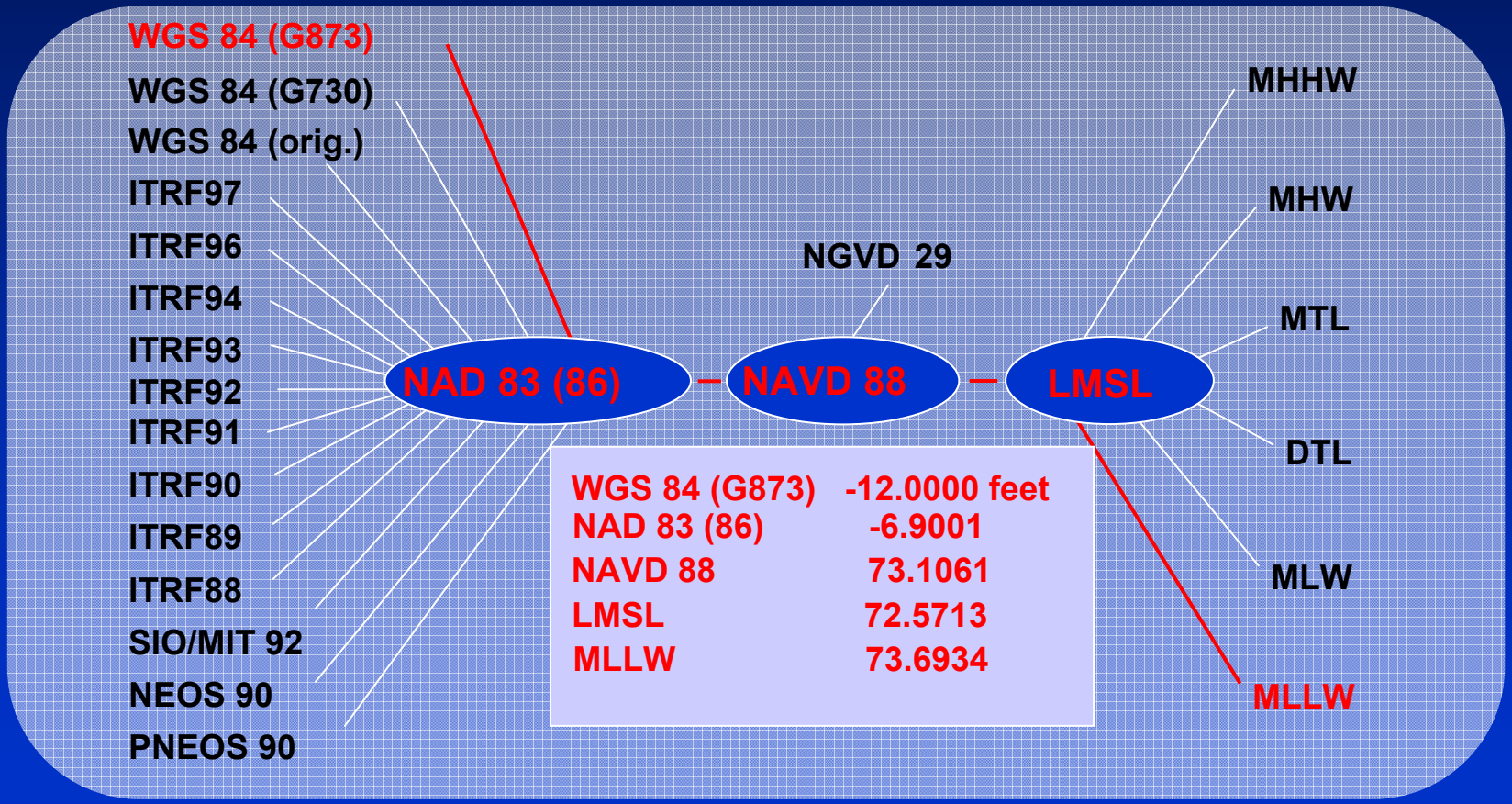
86.39 ft	WGS 84 (G873)	26.33 m
81.33 ft	NAD 83	24.79 m
0.792 ft	MHHW	0.241 m
0.409 ft	MHW	0.125 m
0.0 ft	NAVD 88	0.0 m
-0.535 ft	LMSL	-0.163 m
-0.850 ft	NGVD 29	-0.259 m
-1.495 ft	MLW	-0.456 m
-1.919 ft	MLLW	-0.585 m

Ellipsoid Datums

Orthometric Datums

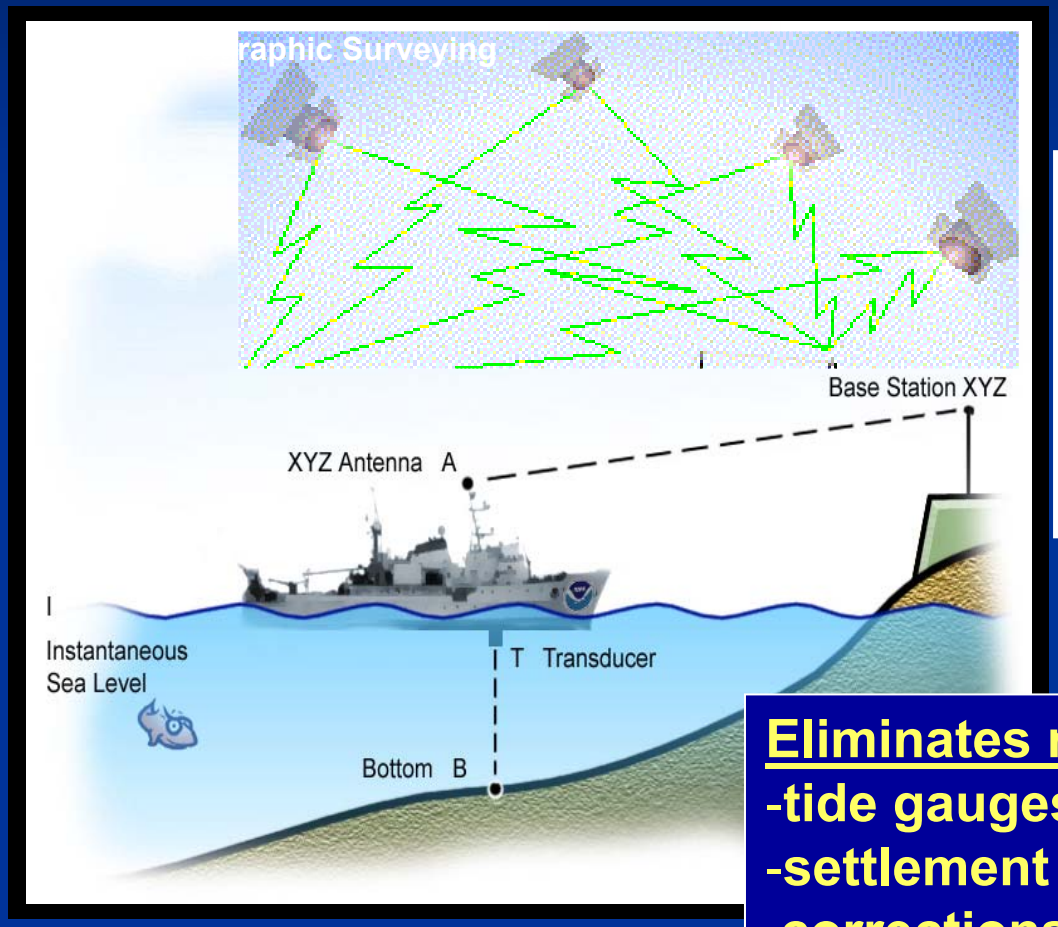
Tidal Datums

The Datum Transformation Roadmap



VDatum Complements Innovative Technologies

Depths are measured "on the fly" or near real time relative to chart datum (MLLW) using VDatum



RTK-GPS Vertically-Referenced Hydrographic Surveys:

Hydrographic data is transformed from ellipsoid datum to MLLW datum

<u>Eliminates need for</u>:

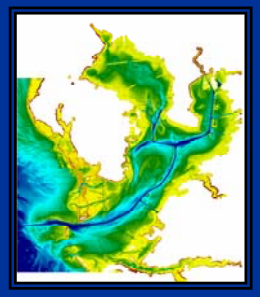
-tide gauges during survey

-settlement & squat corrections for survey vessel

-time-consuming post-survey processing

VDatum Supports Many Other Efforts

USGS Topography

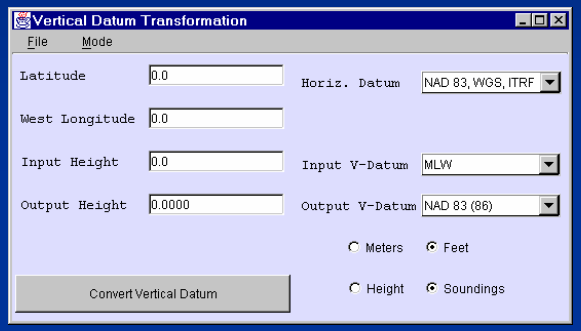


NOAA Bathymetry

Geoid Model

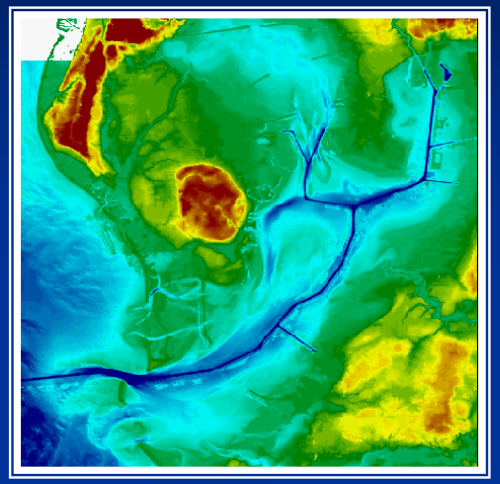
Tidal Model

Ellipsoid Model

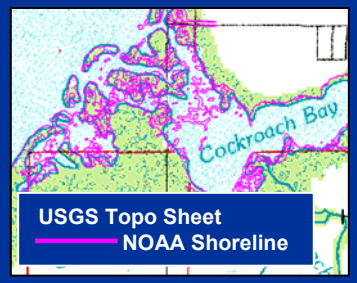


VDatum
(Vertical Datum Transform Tool)

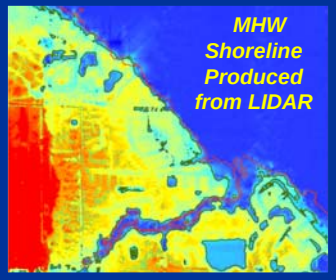
Bathy/Topo
Digital Elevation Model



Resolve NOAA-USGS shoreline inconsistencies



Consistently defined Shoreline from LIDAR data



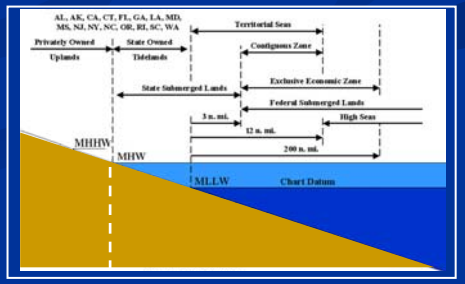
GIS users in the Coastal Community

User-friendly utilization of DEM with new hi-res data in a GIS environment

Charting and Other Applications

National Bathymetric Database

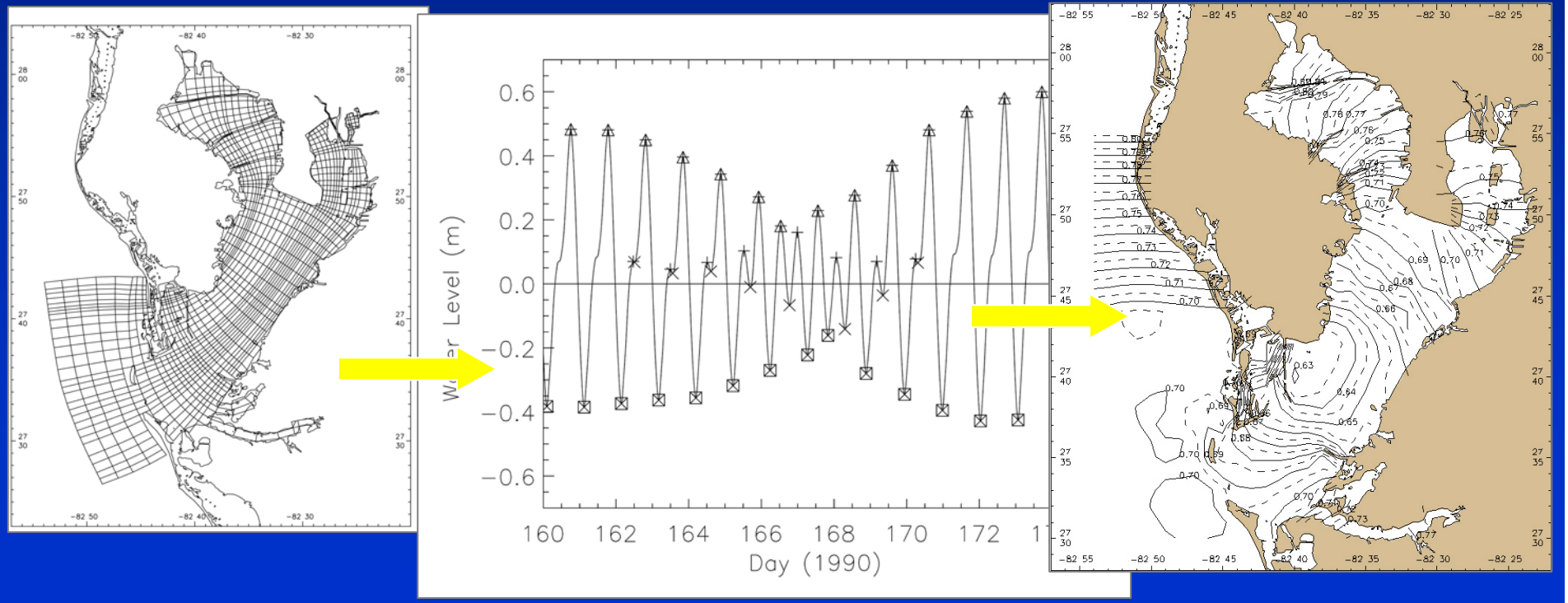
Marine Boundaries and Legal Issues



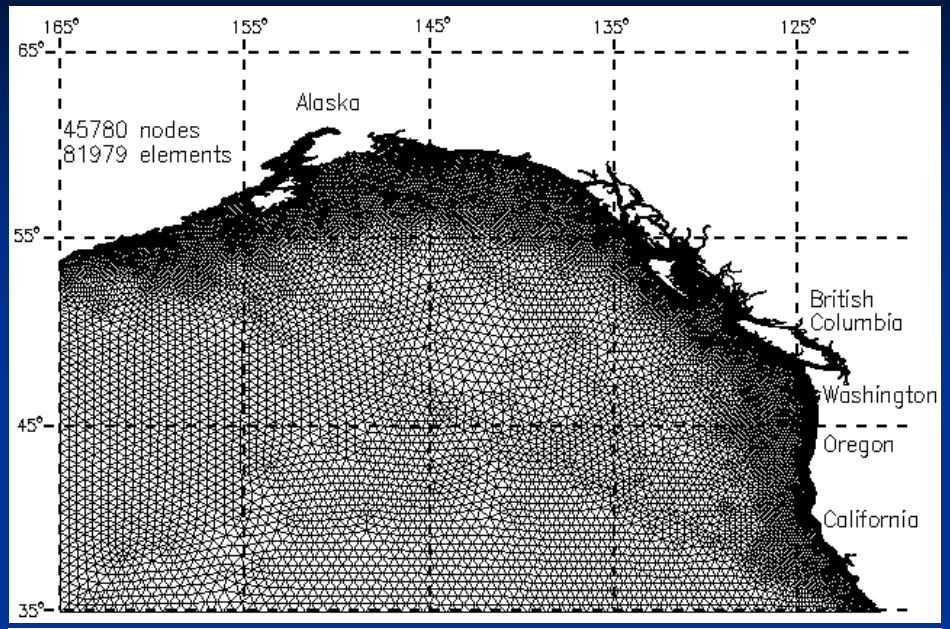
Tidal Datums from Hydrodynamic Models

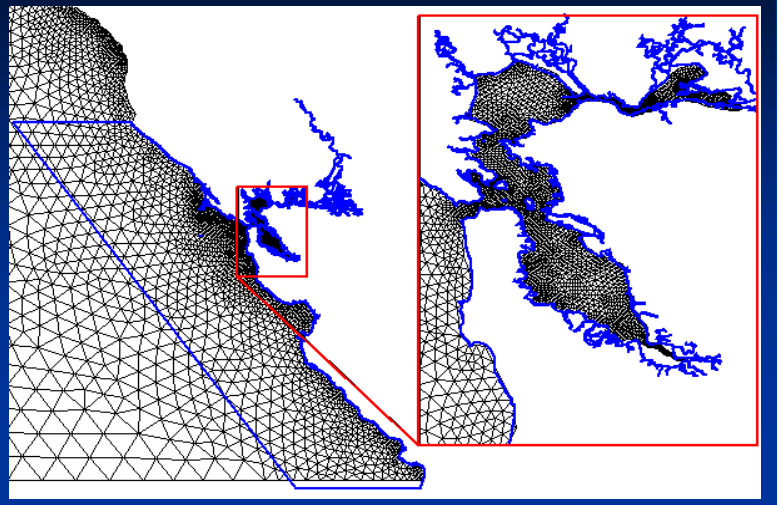
- Drive model with astronomical tides
- Save water levels at each grid cell each 6 minutes (for 1 year)
- Analyze for higher high, high, low, and lower low waters
- Model's RMS error in water level is 4 cm

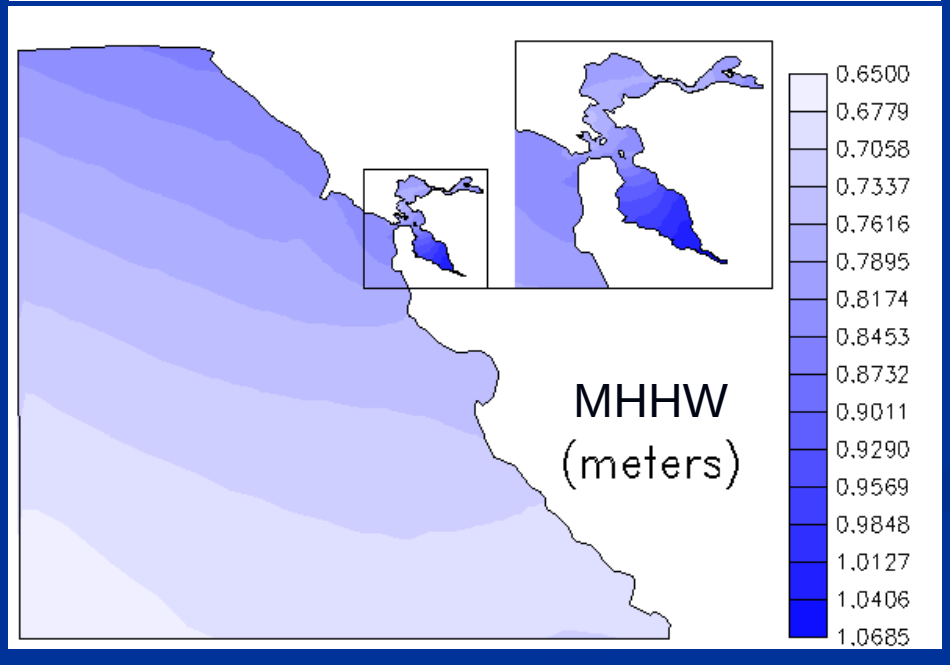
Model **Saved Time Series** **Tidal Datum Fields**



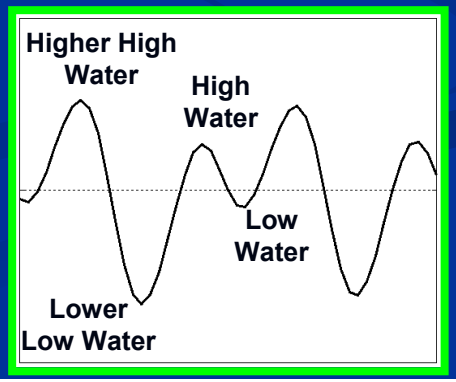
Hydrodynamic Modeling of Tidal Datum Fields







- MHW tidal datum fields (as well as MHHW, MLW, MLLW, MSL, MTL, DTL) from calibrated hydrodynamic models
- Analysis of model-produced time series, then adjusted to provide a best fit to datums at NOS gauges.

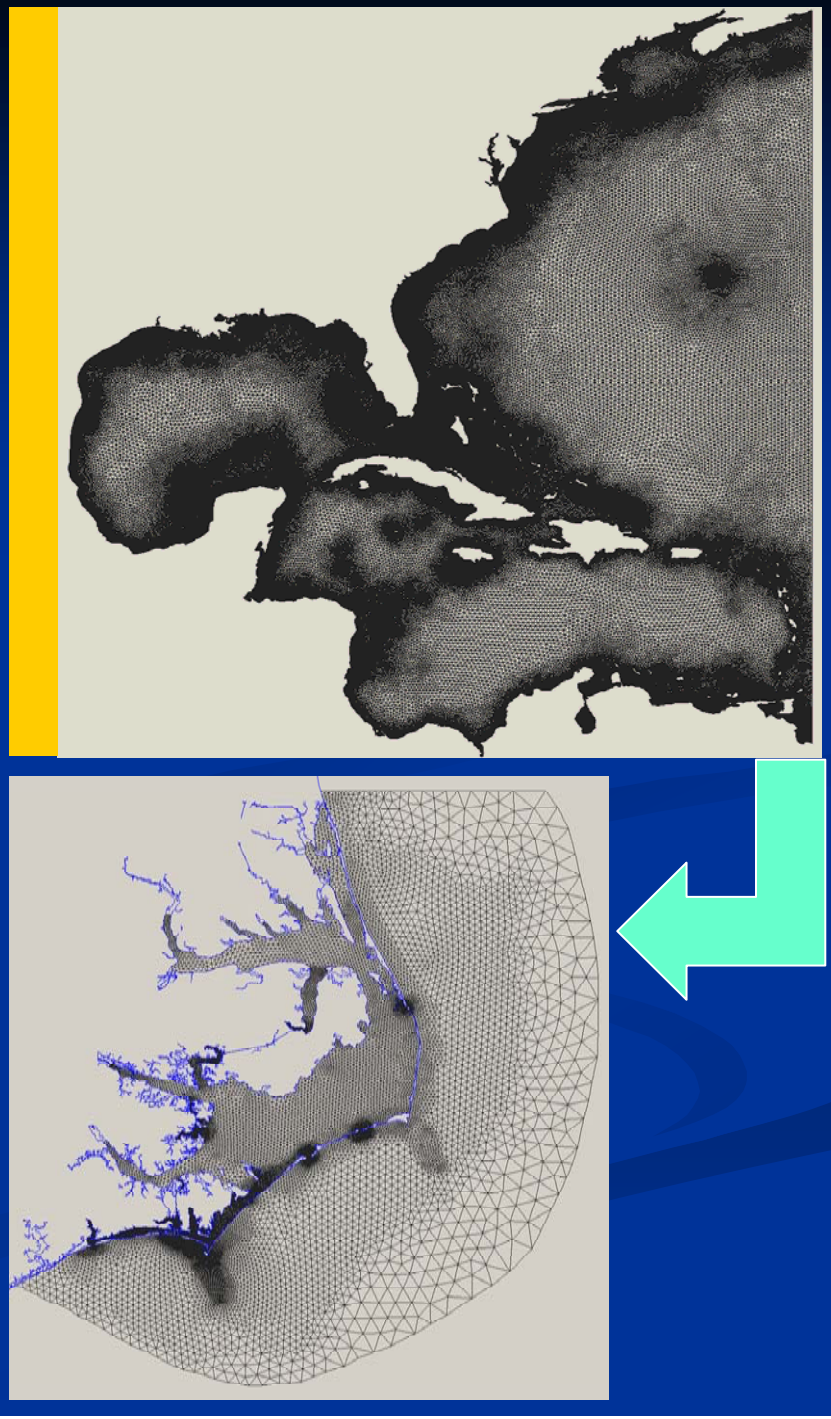


Hydrodynamic Model Setup and Analysis

- Set-up
  - Forced with amp & phase for the M_2,S_2,N_2,K_2,K_1,O_1,and Q_1 tidal constituents from the regional EC2001 tide model
  - 37 day run
  - 2 second time step (36 processors = 5 hours)

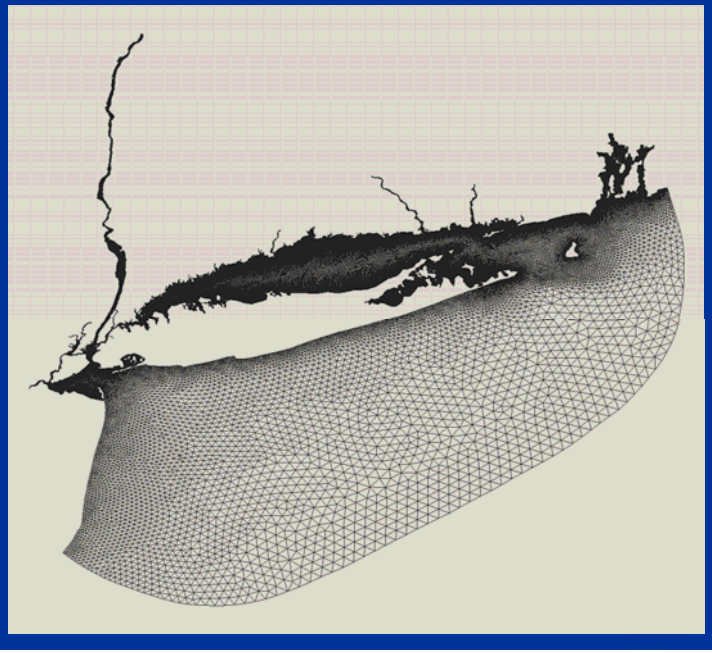
Results

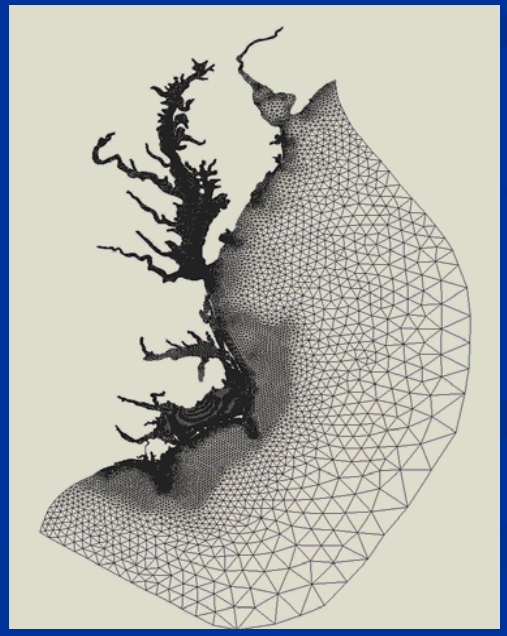
- Record water surface elevation every 6 minutes for final 30 days
- Analyze for tidal datums at every node in the mesh
- Correct results by spatially interpolating errors with TCARI
- Results interpolated onto a regular VDatum marine grid

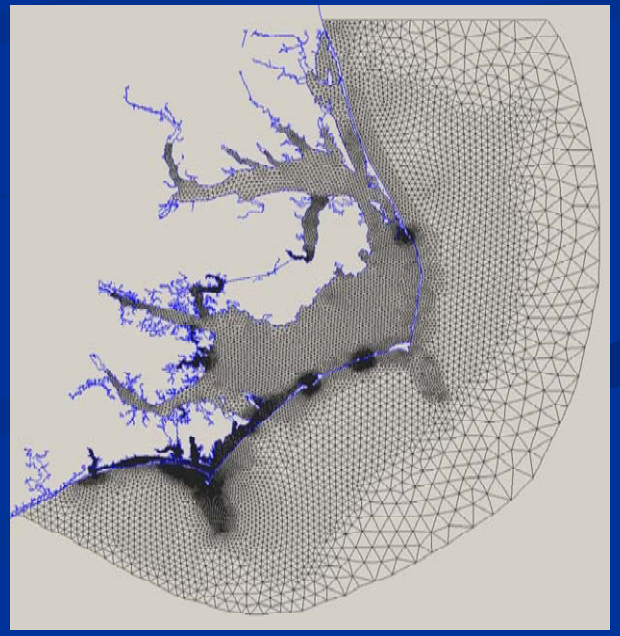


Hydrodynamic Modeling to Simulate the Tides

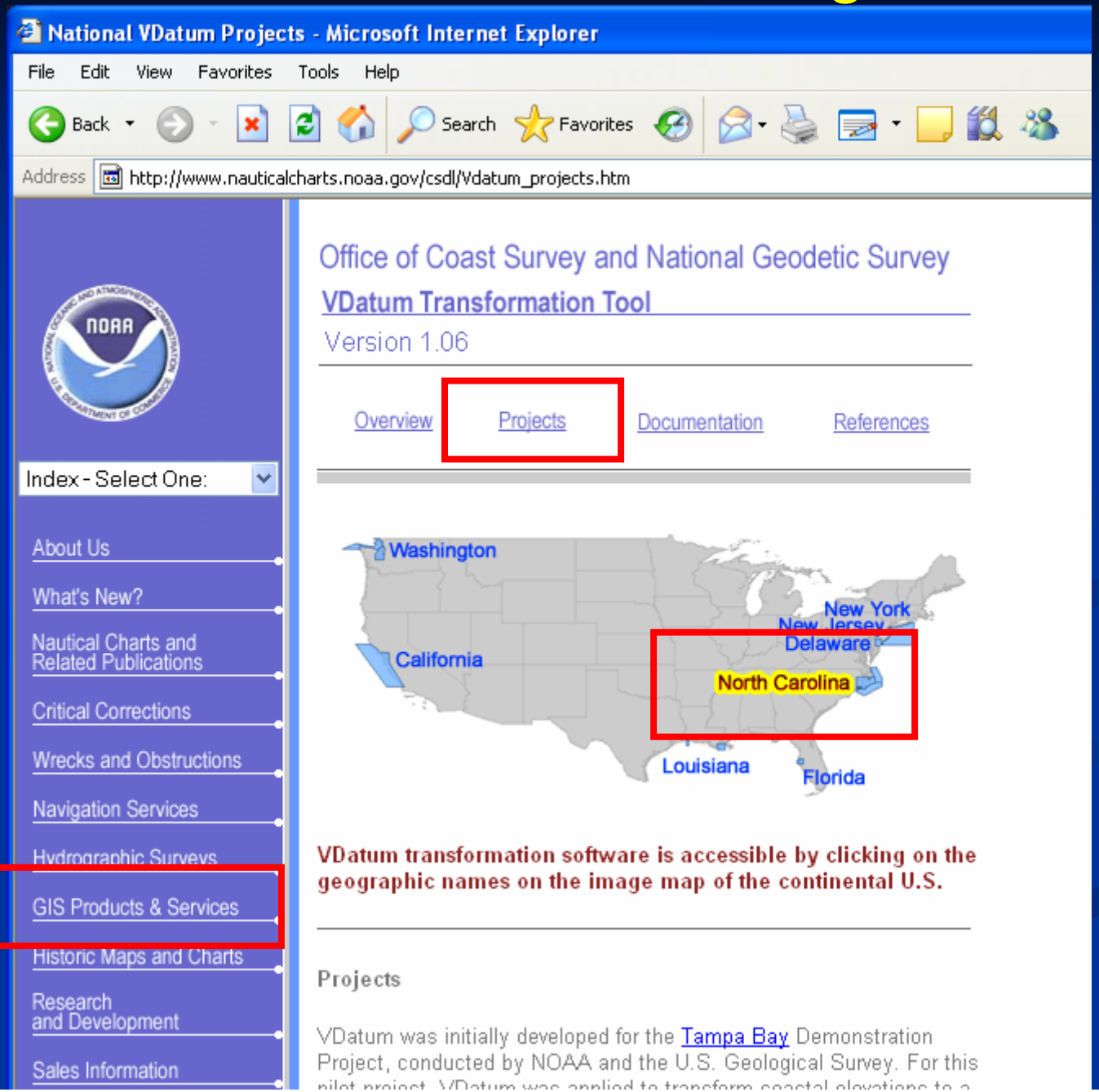
- **NOAA/CSDL normally uses the ADCIRC (*Ad*vanced *Circ*ulation) Model**
- ***2-D depth-integrated shallow water equations***
- ***Finite element solution on triangular grids***
- ***Handles inundation***
- ***Parallelized code (MPI), simulations are made on cluster computers.***







Nauticalcharts.noaa.gov



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- Critical Corrections
- Wrecks and Obstructions
- Navigation Services
- Hydrographic Surveys
- GIS Products & Services
- Historic Maps and Charts
- Research and Development
- Sales Information
- Library
- FAQs

Office of Coast Survey and National Geodetic Survey

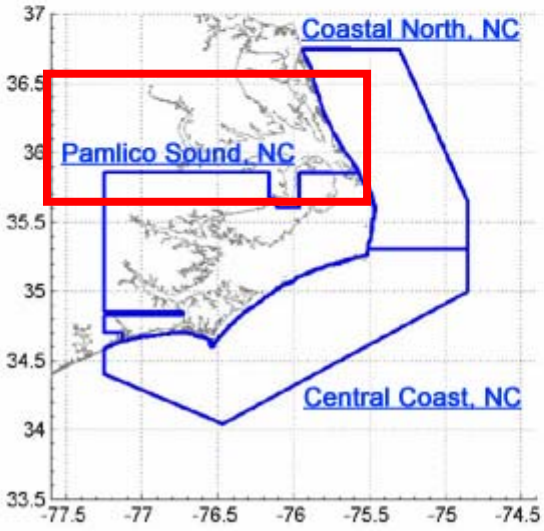
VDatum Transformation Tool

Version 1.06

Overview | Projects | Documentation | References

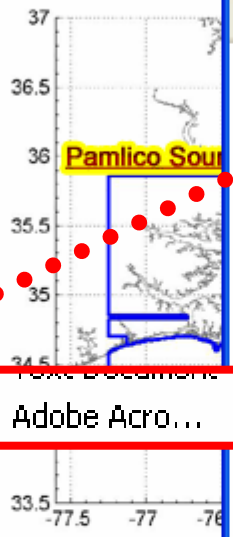
VDatum for North Carolina

VDatum transformation software and documentation are available for download by clicking on the project name on the image map.



VDatum for North Carolina

VDatum transformation so
available for download by
image map.



References

Hess, K. W., Spargo, E., Wo
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S. K., and Zervas, C., 2004:
Interim Technical Report. U.
Oceanic and Atmospheric Ad
NOAA Technical Memorandum NOS CS 5, 25 p.

WinZip - VDatum06_NCpamlis01[1].zip

File Actions Options Help

New Open Favorites Add Extract Encrypt View CheckOut Wizard

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notes_NCpamlis...	Text Document	10/23/2006 2:02 PM	3,361	54%	1,558	VDatum06_...
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sst.gtx	GTX File	3/21/2006 4:27 PM	4,158,032	97%	129,209	VDatum06_...
Vcn.gtx	GTX File	10/27/2005 2:45 PM	59,386	61%	23,445	VDatum06_...
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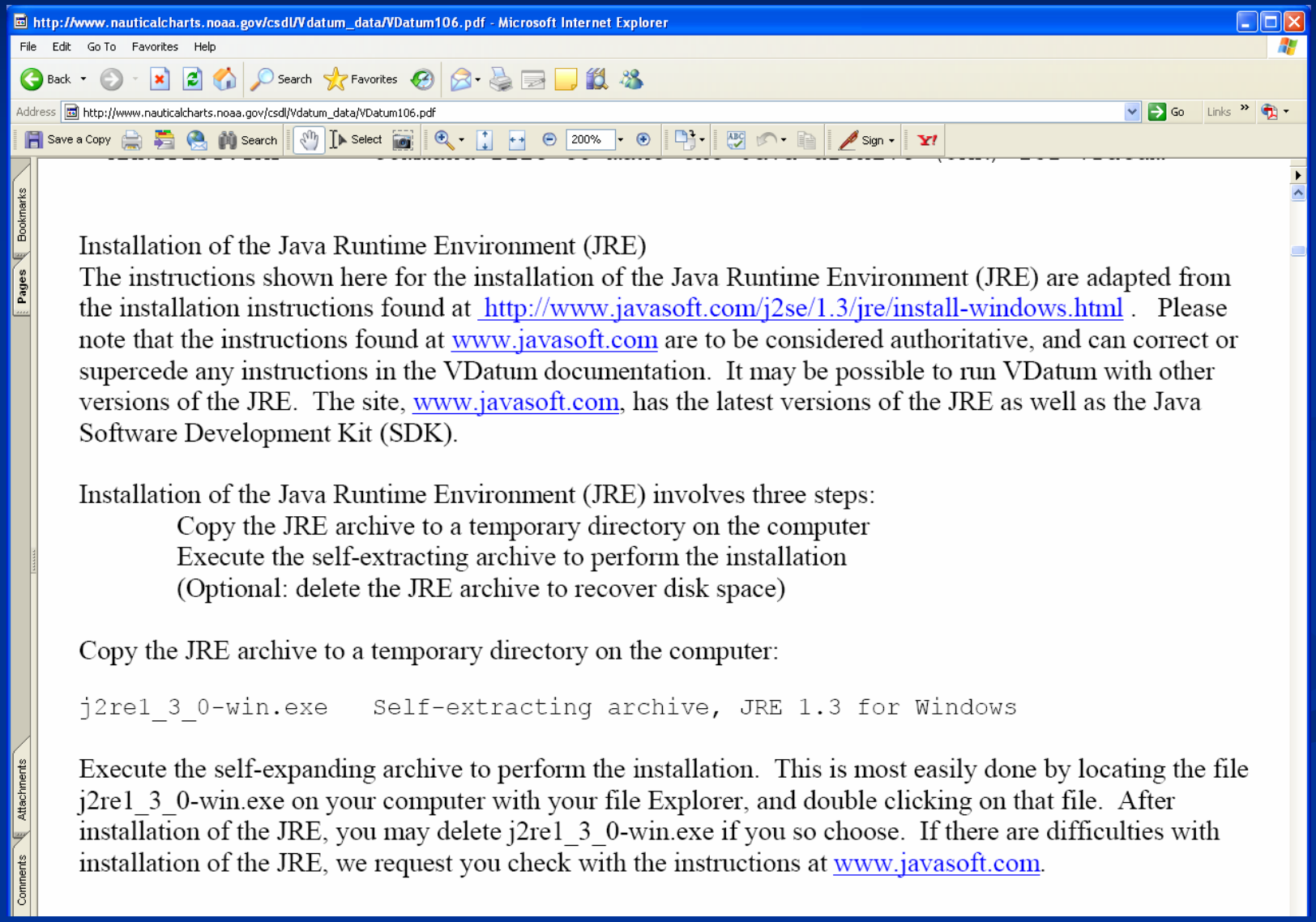
Must have
Java Runtime Environment



Installation of the Java Runtime Environment (JRE)
The instructions shown here for the installation of the Java Runtime Environment (JRE) are adapted from the installation instructions found at http://www.javasoft.com/j2se/1.3/jre/install-windows.html . Please note that the instructions found at www.javasoft.com are to be considered authoritative, and can correct or supercede any instructions in the VDatum documentation. It may be possible to run VDatum with other versions of the JRE. The site, www.javasoft.com, has the latest versions of the JRE as well as the Java Software Development Kit (SDK).

Installation of the Java Runtime Environment (JRE) involves three steps:

Copy the JRE archive to a temporary directory on the computer
Execute the self-extracting archive to perform the installation
(Optional: delete the JRE archive to recover disk space)

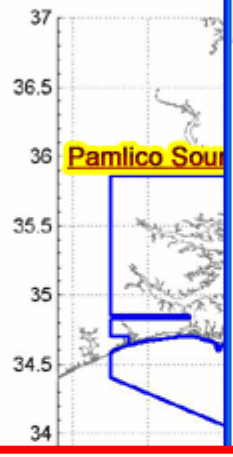
Copy the JRE archive to a temporary directory on the computer:

```
j2re1_3_0-win.exe    Self-extracting archive, JRE 1.3 for Windows
```

Execute the self-expanding archive to perform the installation. This is most easily done by locating the file j2re1_3_0-win.exe on your computer with your file Explorer, and double clicking on that file. After installation of the JRE, you may delete j2re1_3_0-win.exe if you so choose. If there are difficulties with installation of the JRE, we request you check with the instructions at www.javasoft.com.

VDatum for North Carolina

VDatum transformation so
available for download by
image map.



References

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g99.gtx	GTX File	9/6/2005 5:34 PM	393,224	69%	122,787	VDatum06_...
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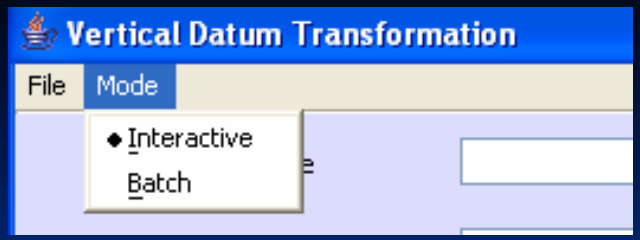
Running the Tool



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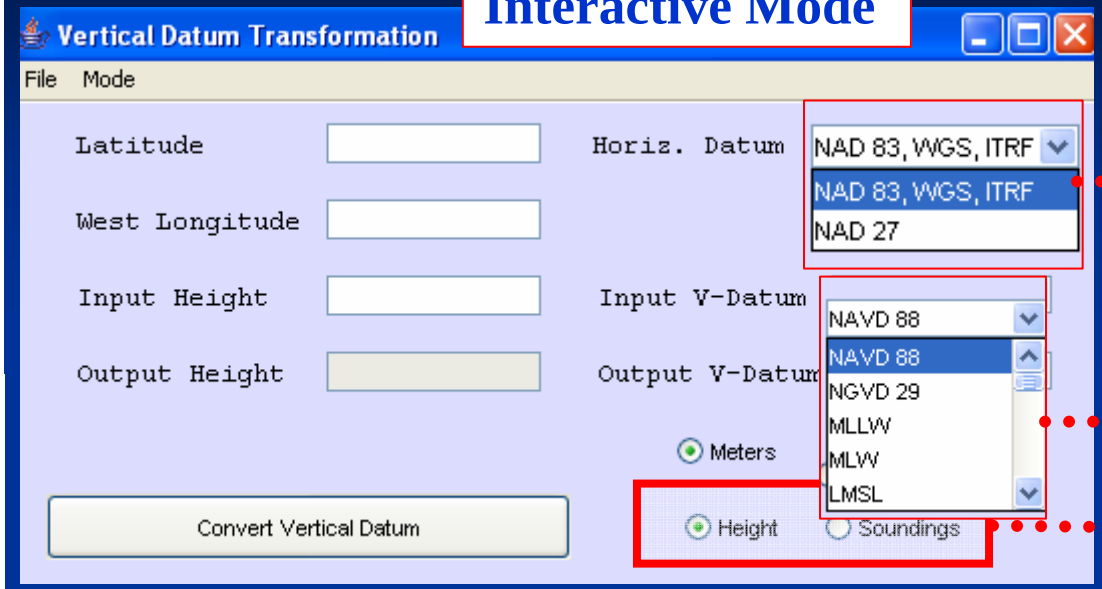


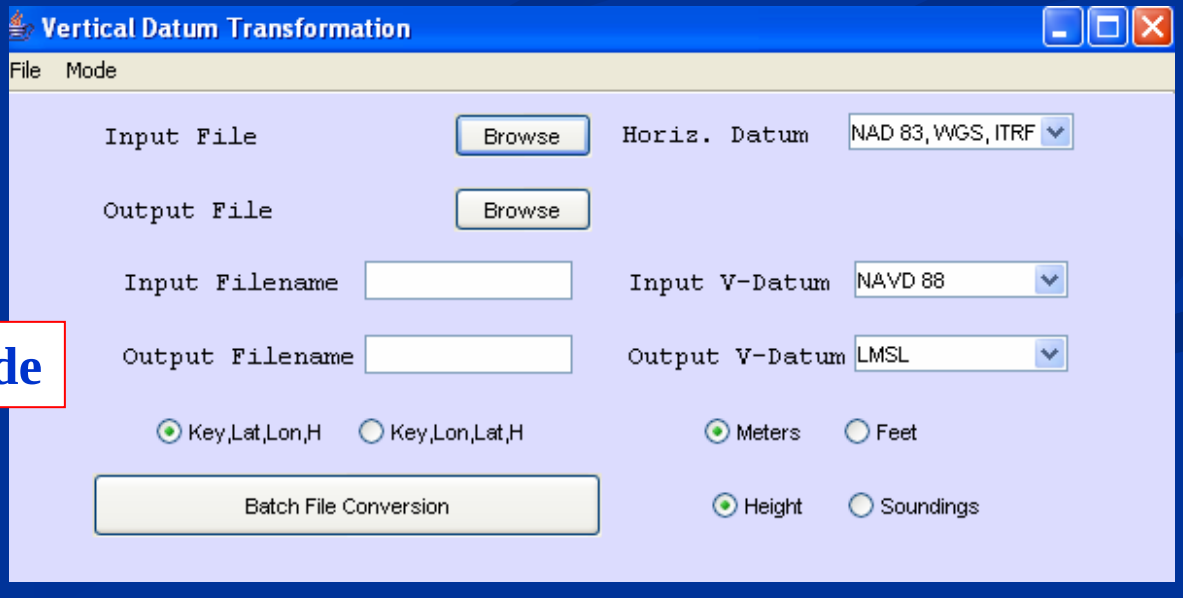
Select horizontal datum

input topography is +

Select vertical datum – input and output

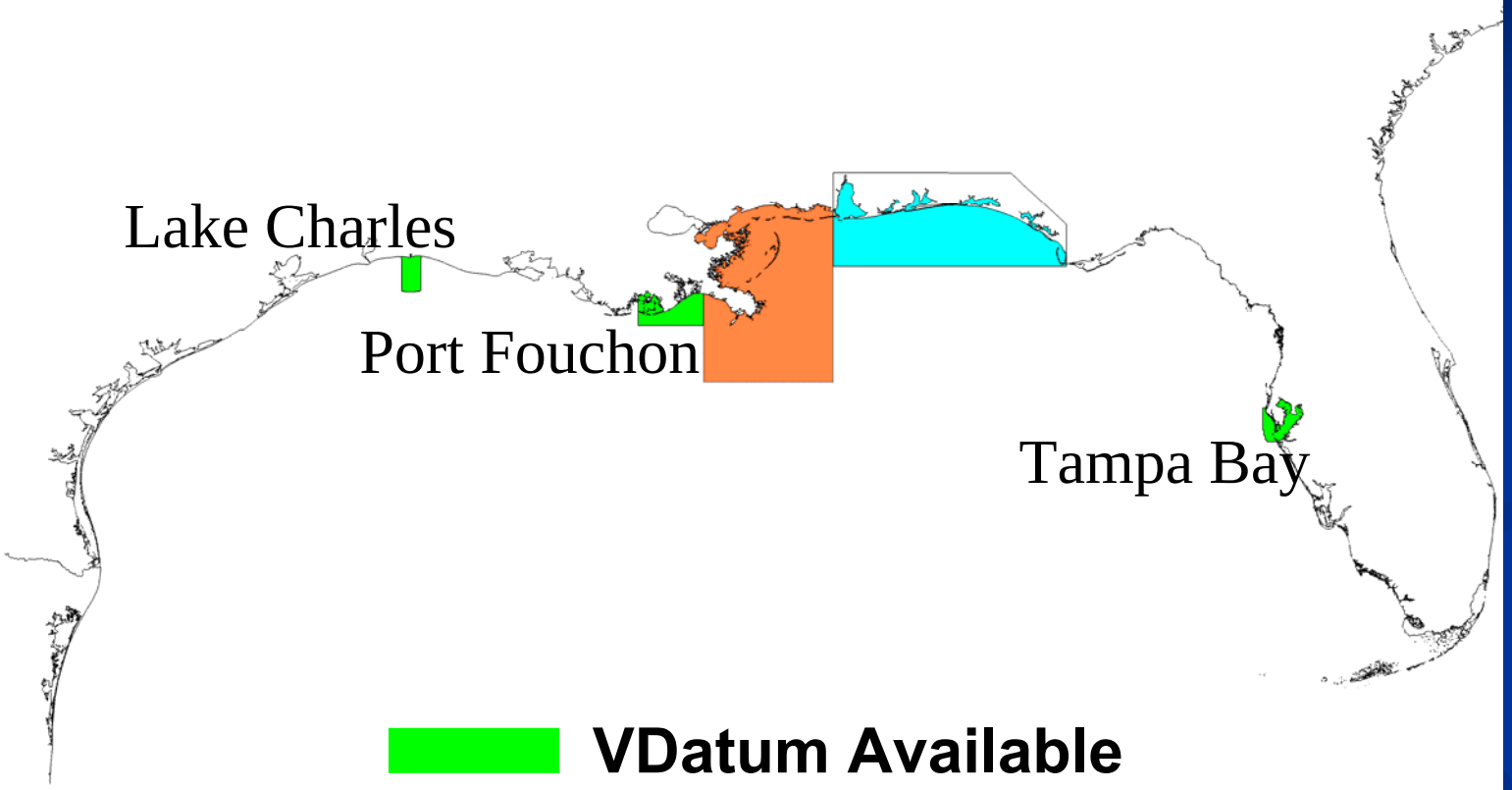
input bathymetry is +

Batch Mode

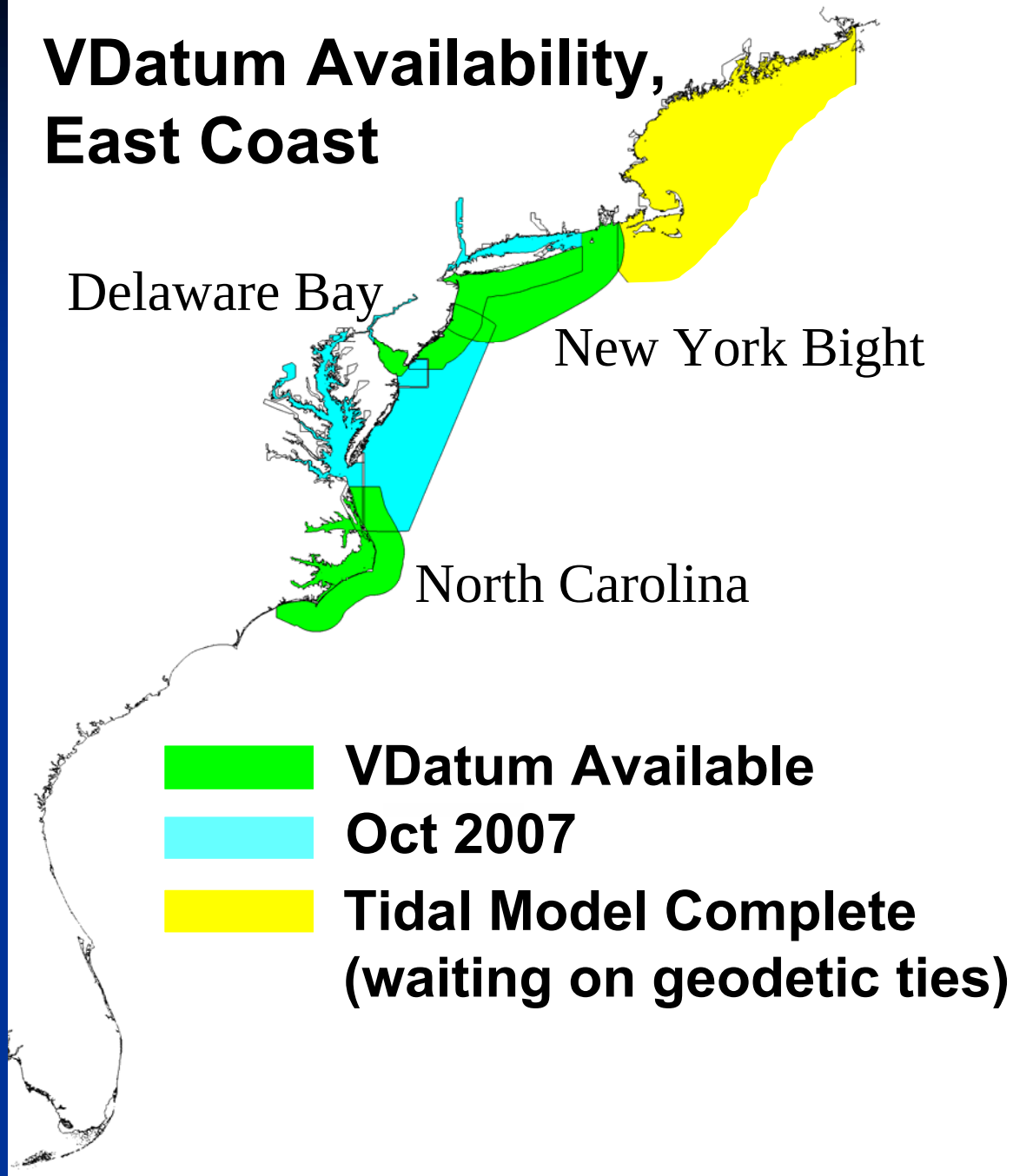


VDatum Availability, West Coast

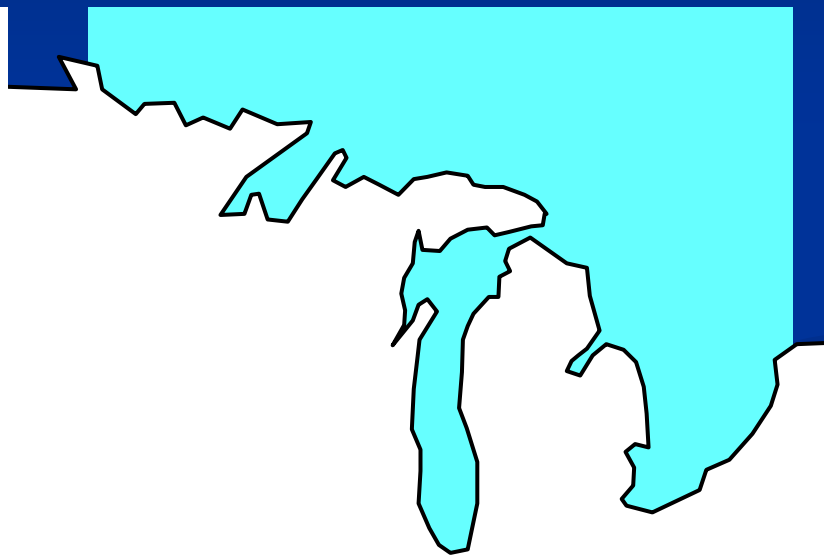
VDatum Availability, Gulf Coast



VDatum Availability, East Coast

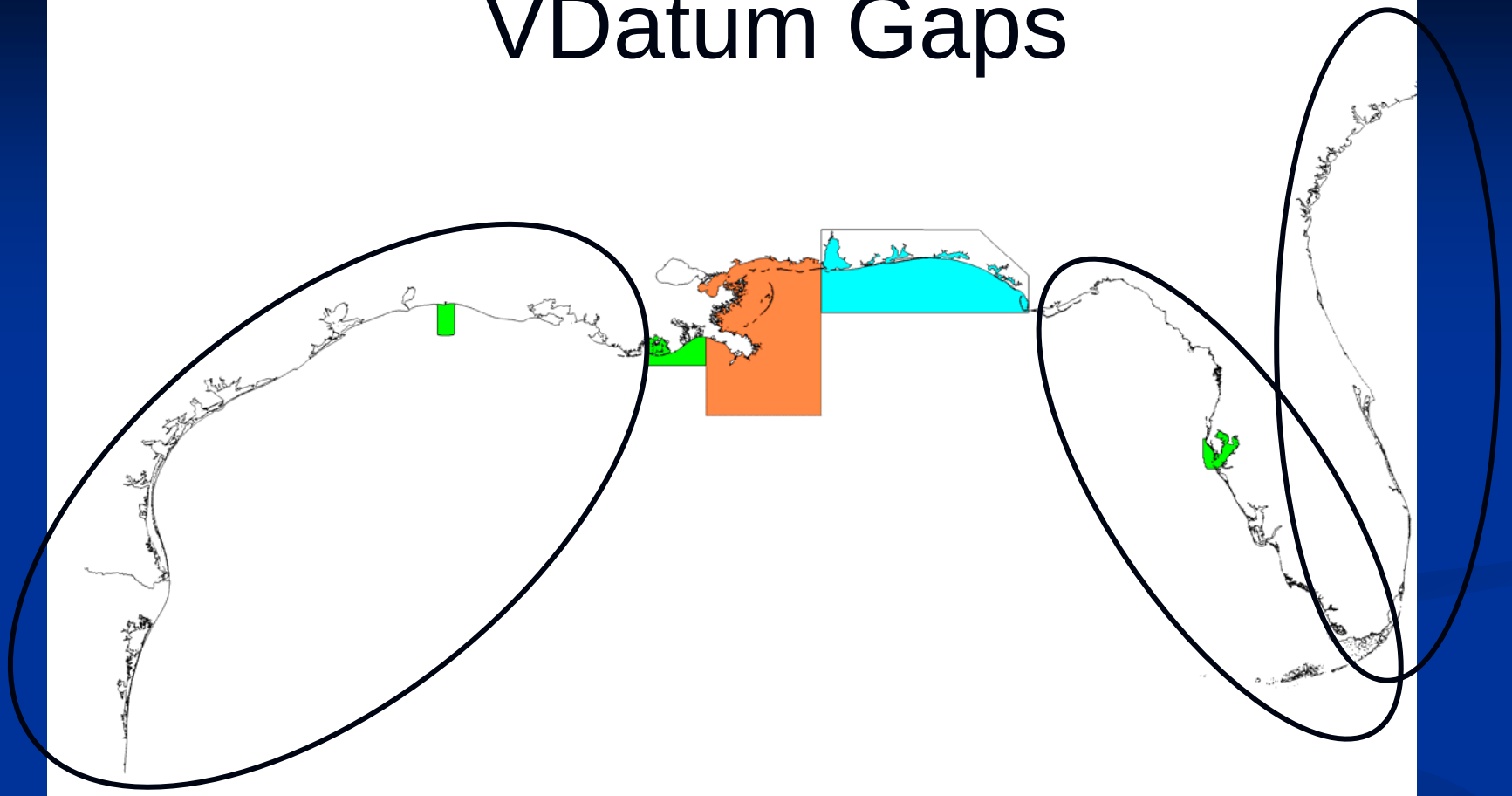


VDatum Availability, Great Lakes



Dec 2007

VDatum Gaps



Improvements in Next Version

Choose region w/o rerunning executable

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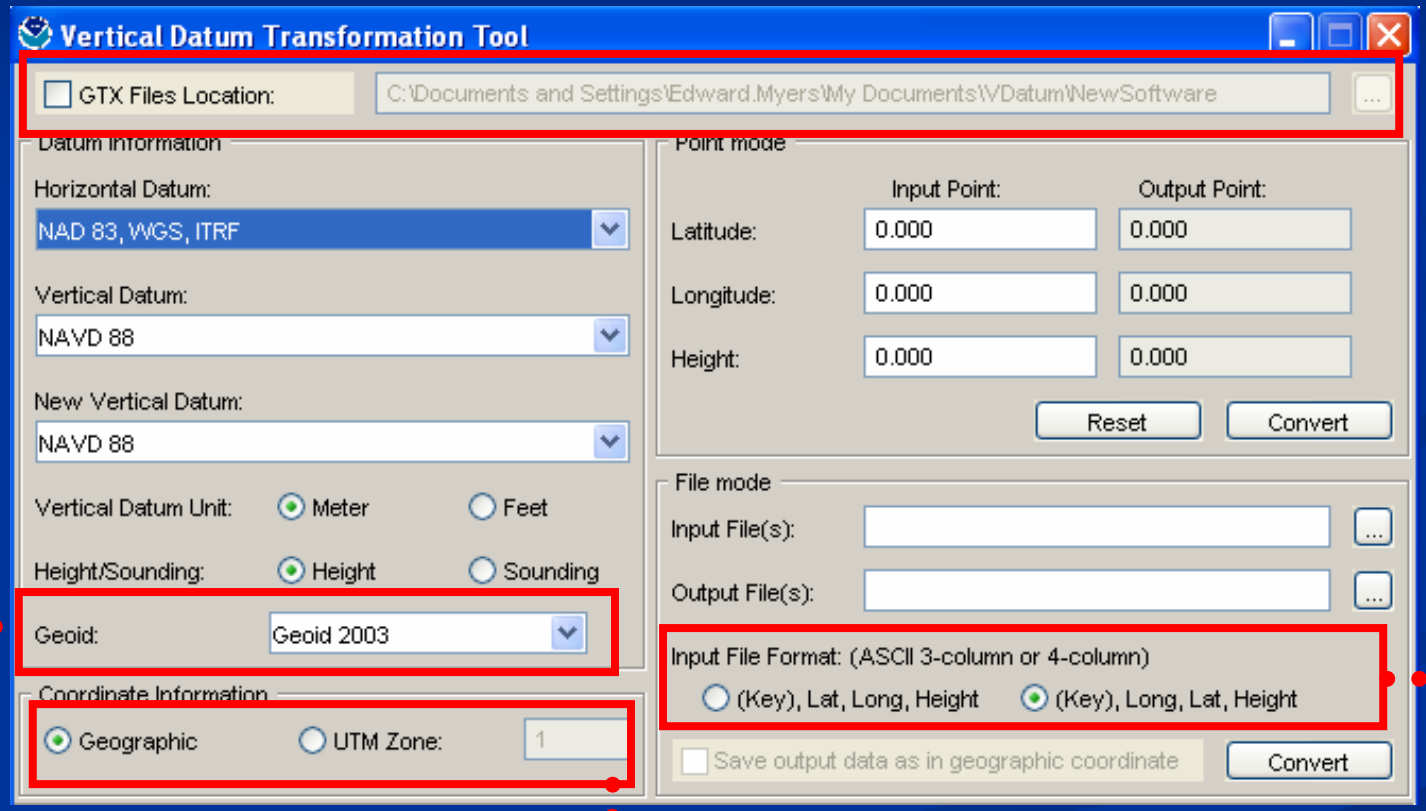


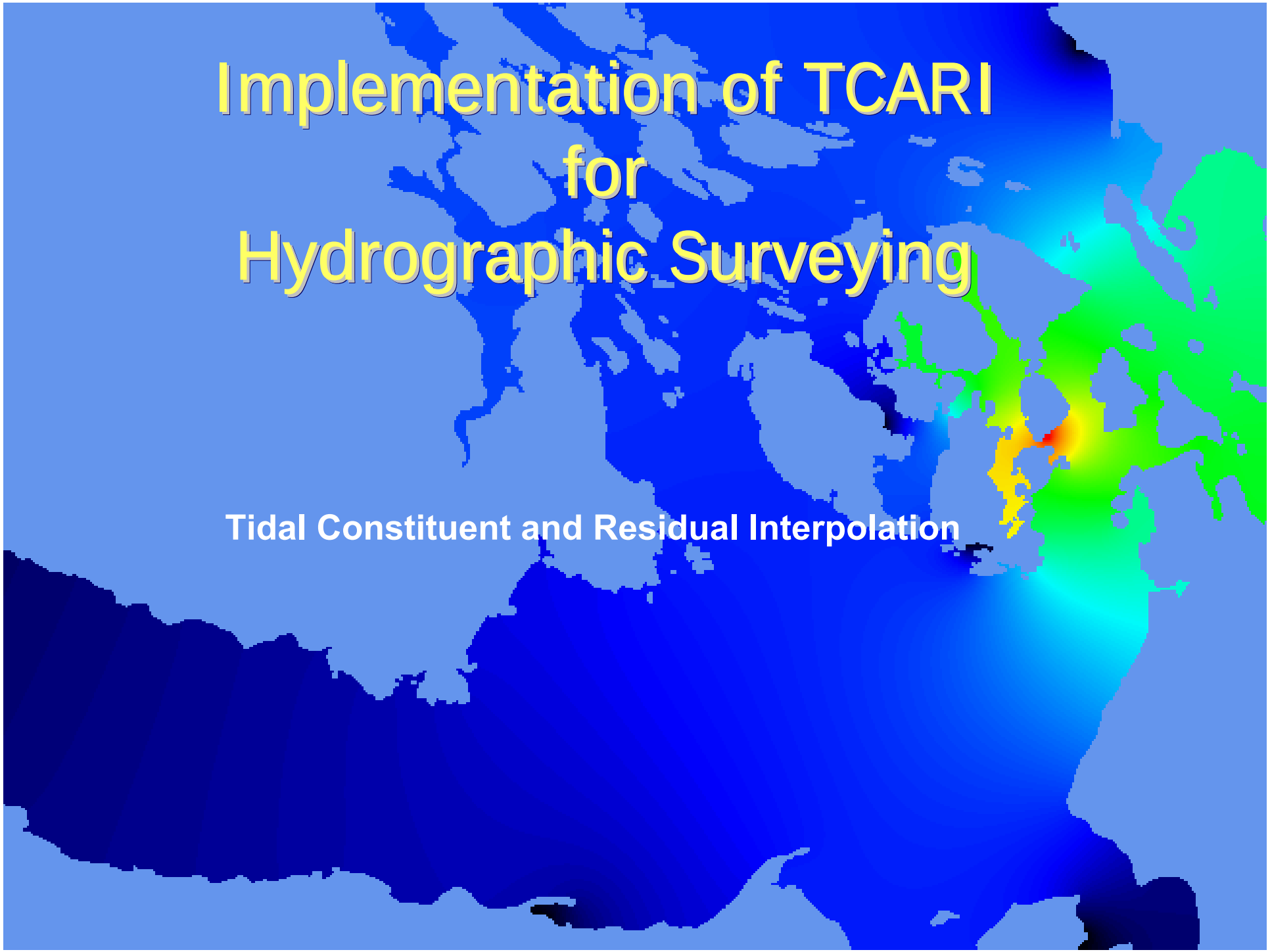
2003 geoid model added

Lat, Long or UTM

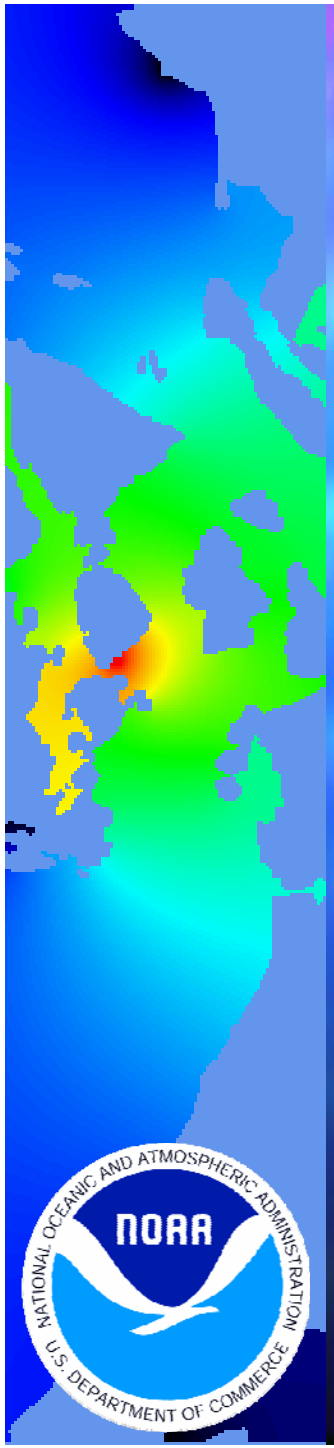
Future VDatum Developments

- Incorporation of State Plane Coordinates
- Development of a National VDatum
- Evaluating extending VDatum inland
- Provide uncertainty estimates in metadata
- Improvements to downloadable software
- New web-based tools for interacting with VDatum results

Implementation of TCARI for Hydrographic Surveying



Tidal Constituent and Residual Interpolation

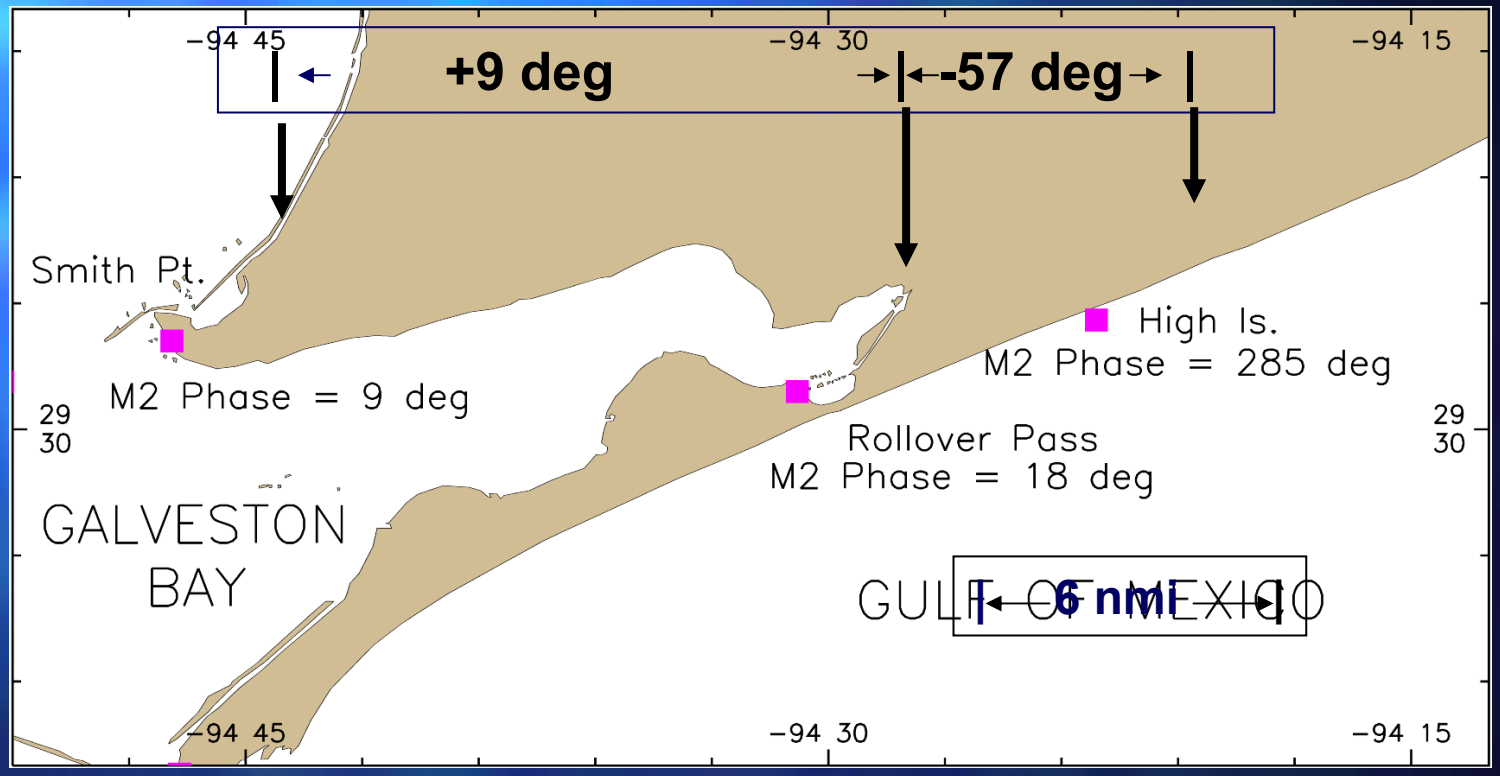


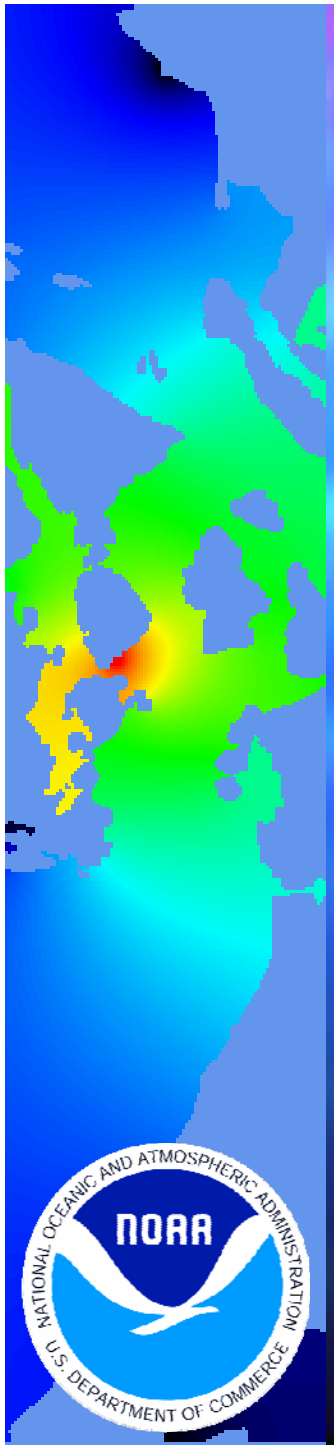
Tidal Constituent And Residual Interpolation (TCARI)

- Created in 1995 at Coast Survey Development Laboratory by Dr. Kurt Hess.
- Re-Coded in Python for PYDRO by Barry Gallagher (Hydrographic System and Technology Program).
- Uses formal mathematics to interpolate tidal constituents, residual water levels, and vertical datum across survey area.
- TCARI overcomes discrete zoning weaknesses.
- Also provides the means of modeling Chart Datum-Ellipsoid separation.

Spatial Interpolation:
Why a New Method Instead of Linear?

-- Because of intervening land --





Overview of TCARI

Spatial interpolation (Laplace Equation)

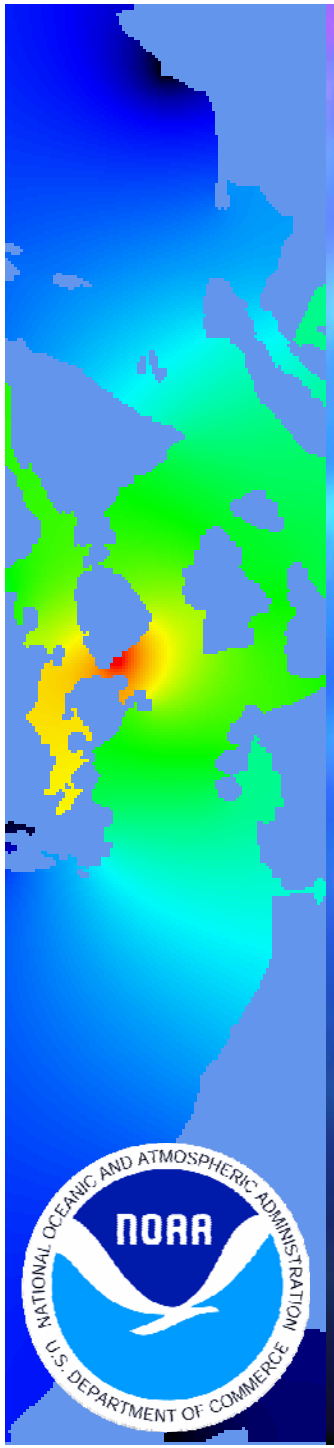
- from tide station locations with known values of components
  - harmonic constituents, residuals, and datum offsets
- to anywhere else in local region at any time
- sum of weighted components

TCARI equations

Interpolation by Laplace's Equation: $\Delta^2 f = 0$

Subject to boundary conditions: $f(x_i, y_i) = f_i^{obs}$

f = datum, amp, cos(phase) $\partial f/\partial n = \alpha \overline{\partial f/\partial n}$



Overview of TCARI

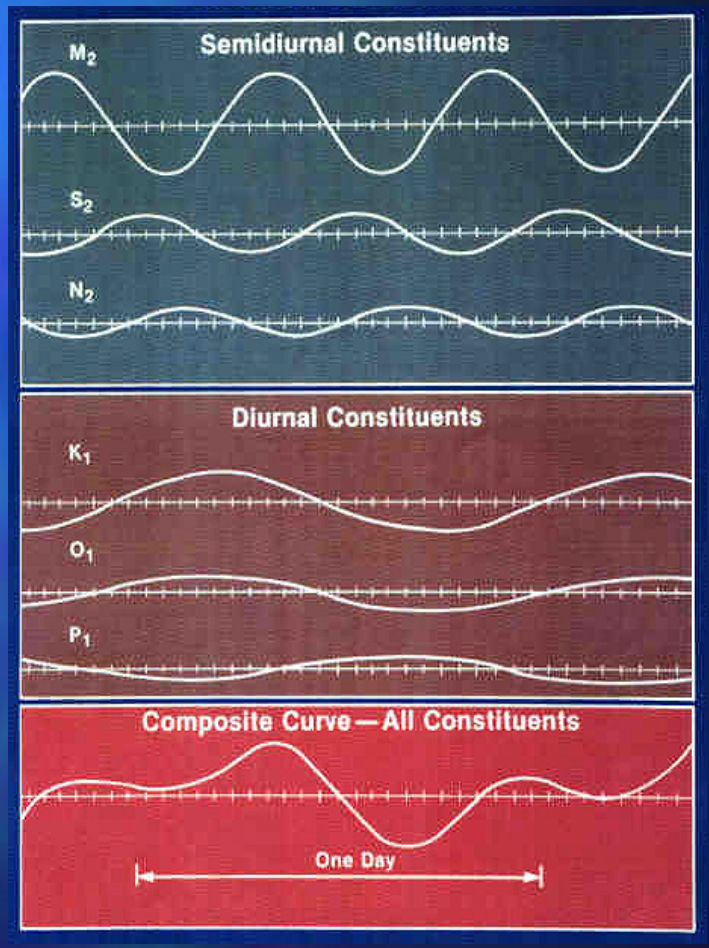
TCARI Separately Interpolates:

- astronomical tide = Sum of Harmonic Constituents
  (i.e. predicted tides)
- residual water level = Observed – Predicted
- datum offset = MSL – MLLW
  or MSL – ellipsoid, etc.

tide correction = astronomical tide
+ residual
+ datum offset

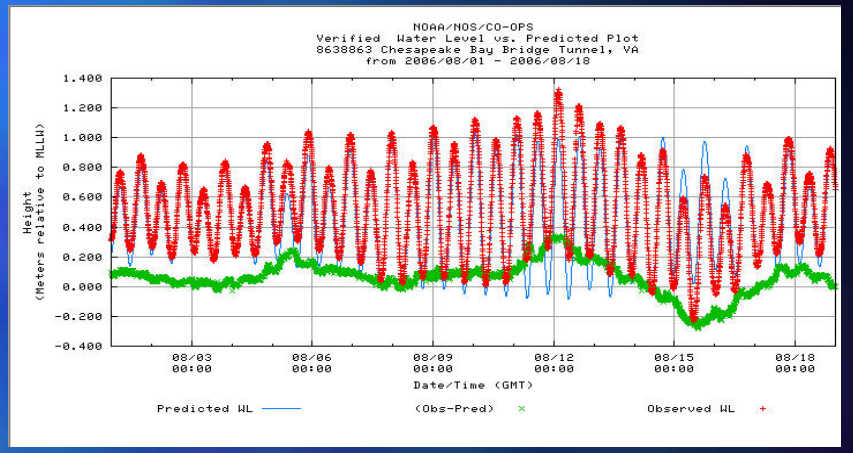
TCARI

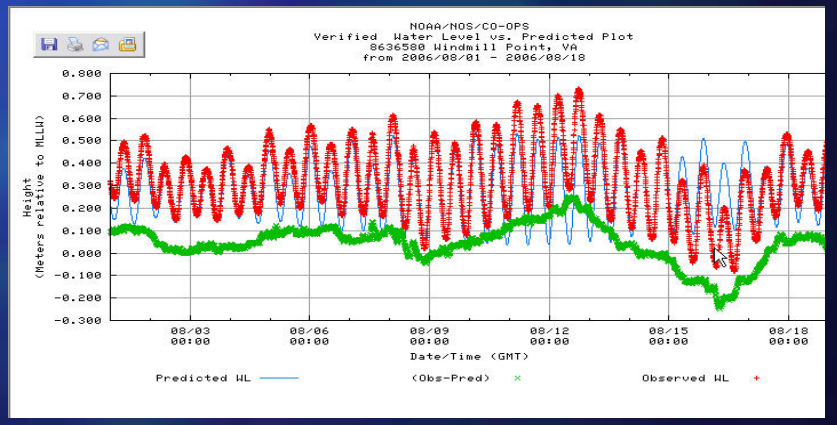
- Tidal component may be broken down into its “harmonic constants”.
- 37 Used by NOAA.

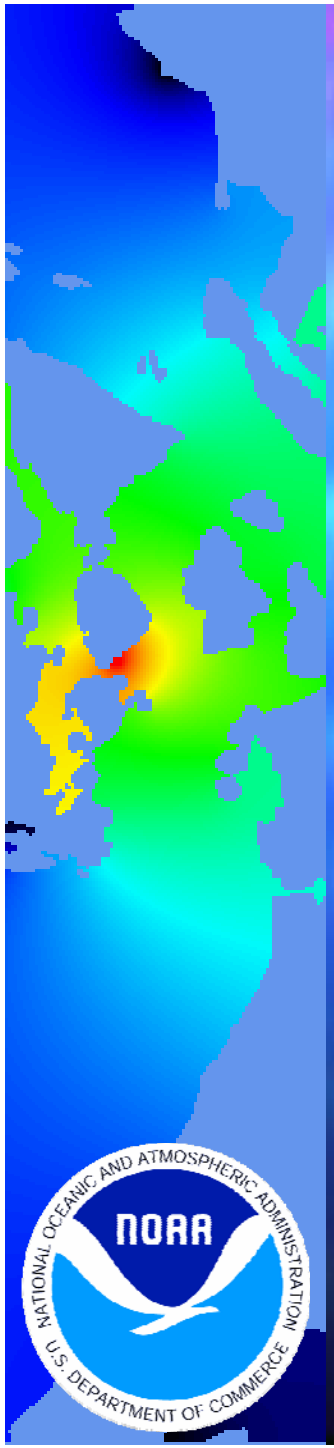


TCARI

- Tidal portion induced by the interaction between the earth, sun, and moon.
- Non-tidal is induced by weather and riverine discharge.



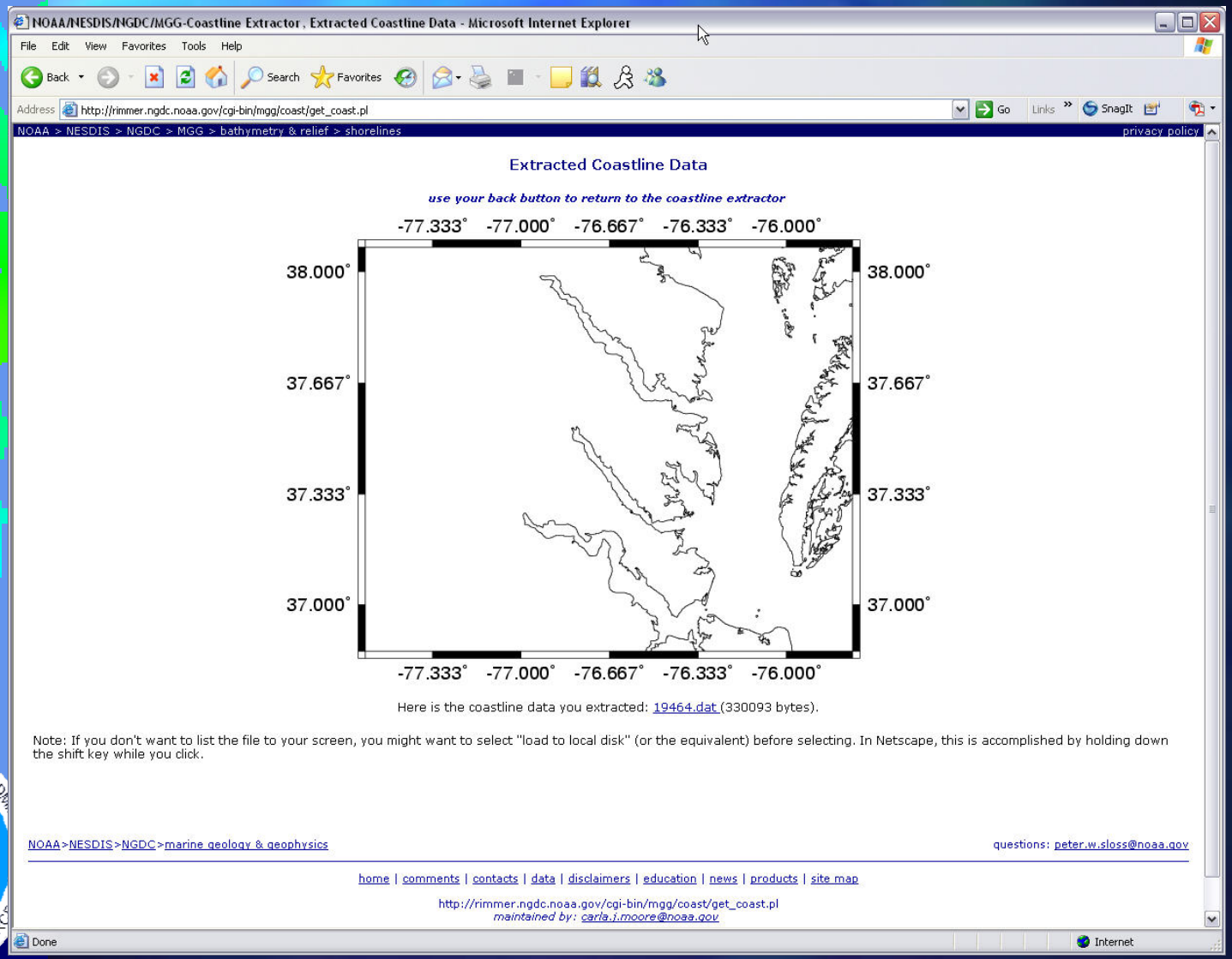




Triangulated Mesh Creation

- Load Vector Shoreline – National Geophysical Data Center (NGDC) website
- Clean Shoreline
- Load Tide Stations
- Create Mesh Grid

Example of Running the TCARI Software: First extract a coastline



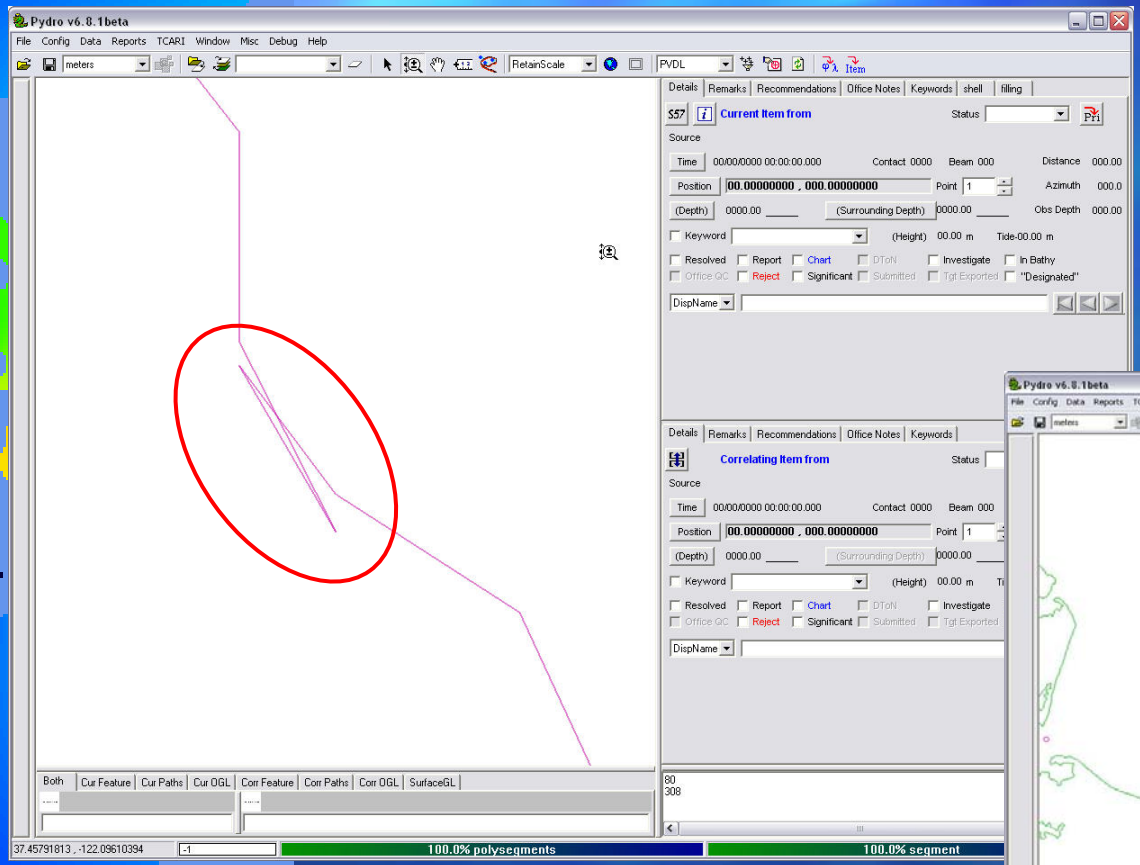
Input Observed Datums into File

36.38.-77.-75.TCARI.txt - Notepad

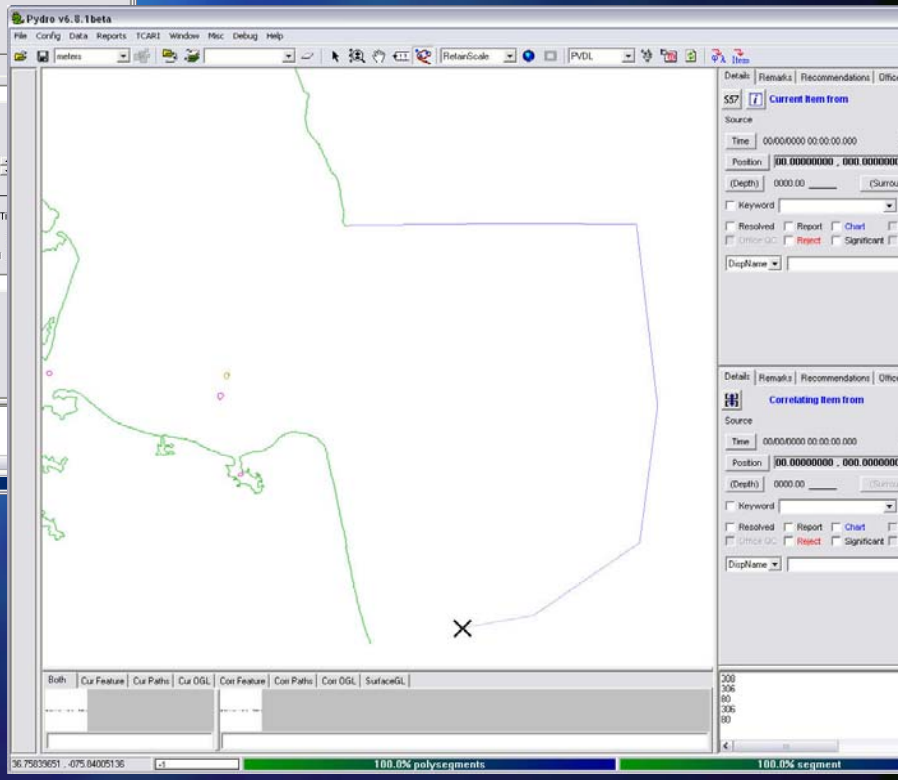
File Edit Format View Help

N	Station	#	ST	Name	Longitude	Latitude	Beg Mon	Beg Day	BegYear	End Mon	End Day	EndYear	Pub Mon
1	8632200	2	VA	KIPTOPEKE, CHESAPEAKE BAY	-75.988333	37.166667	9.00	21.00	2005.00	-99.99	-99.99	-99.99	7.00
2	8633532	1	VA	TANGIER ISLAND	-75.993333	37.828333	3.00	14.00	2005.00	-99.99	-99.99	-99.99	4.00
3	8635750	1	VA	LEWISETTA, POTOMAC RIVER	-76.465000	37.995000	7.00	20.00	1990.00	-99.99	-99.99	-99.99	4.00
4	8636580	1	VA	WINDMILL POINT, RAPPAHANNOCK RIVER	-76.290000	37.615000	12.00	16.00	2004.00	-99.99	-99.99	-99.99	4.00
5	8637624	1	VA	GLOUCESTER POINT, YORK RIVER	-76.500000	37.246667	4.00	29.00	1991.00	9.00	18.00	2003.00	4.00
6	8637689	2	VA	YORKTOWN USCG TRAINING CENTER, YORK R.	-76.478333	37.226667	4.00	24.00	2004.00	-99.99	-99.99	-99.99	4.00
7	8638424	1	VA	KINGSMILL, JAMES RIVER	-76.663333	37.220000	6.00	6.00	2003.00	9.00	18.00	2003.00	4.00
8	8638433	1	VA	SCOTLAND, JAMES RIVER	-76.783333	37.185000	6.00	5.00	2003.00	9.00	18.00	2003.00	9.00
9	8638489	1	VA	PUDDLEDOCK SAND & GRAVEL	-77.371667	37.266667	8.00	1.00	2003.00	9.00	15.00	2003.00	1.00
10	8638610	1	VA	SEWELLS POINT, HAMPTON ROADS	-76.330000	36.946667	1.00	13.00	2006.00	-99.99	-99.99	-99.99	9.00
11	8638863	2	VA	CHESAPEAKE BAY BRIDGE TUNNEL	-76.113333	36.966667	5.00	10.00	2005.00	-99.99	-99.99	-99.99	10.00

Clean up coastline file

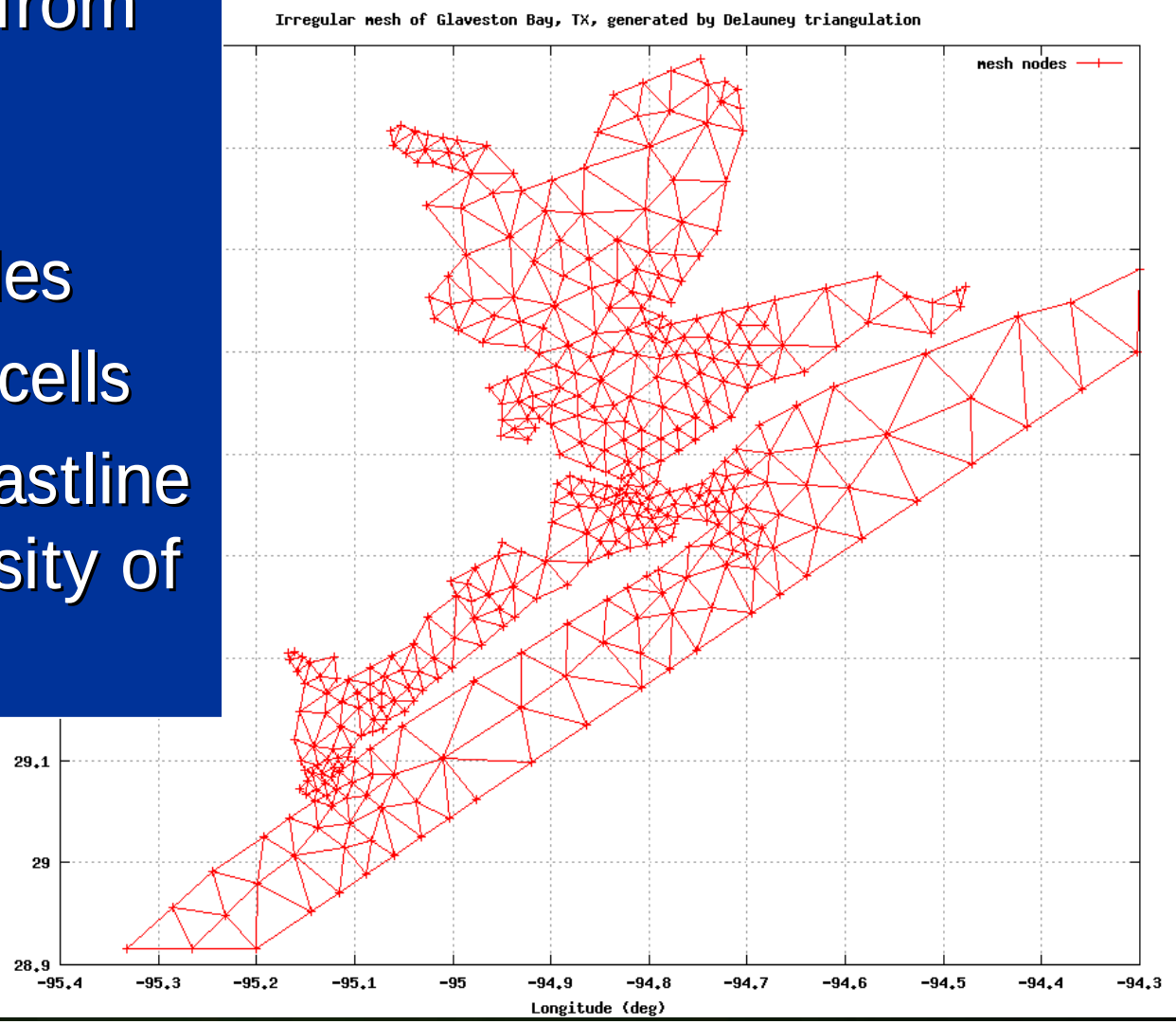


Create an open ocean boundary

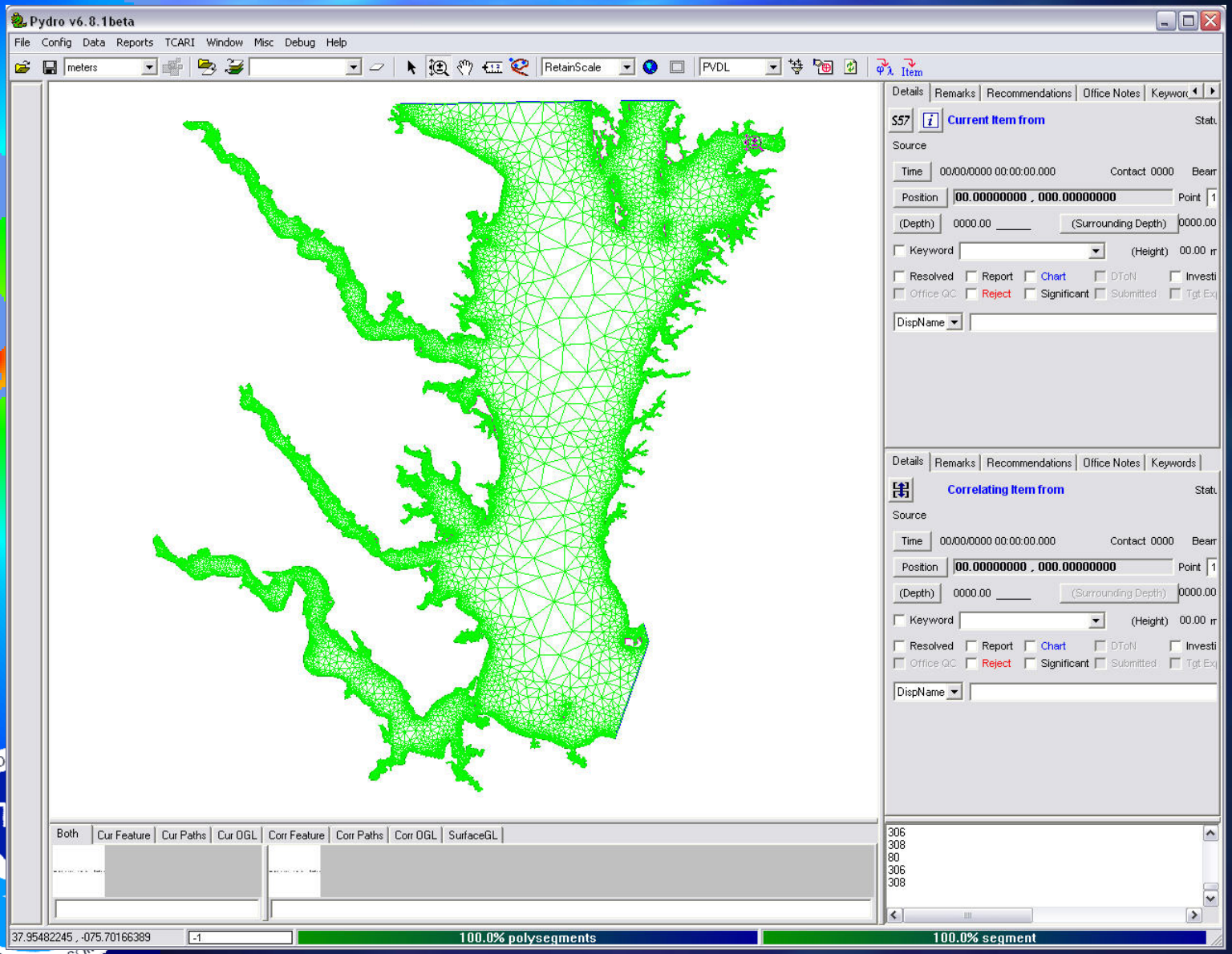


TCARI: Mesh Generation

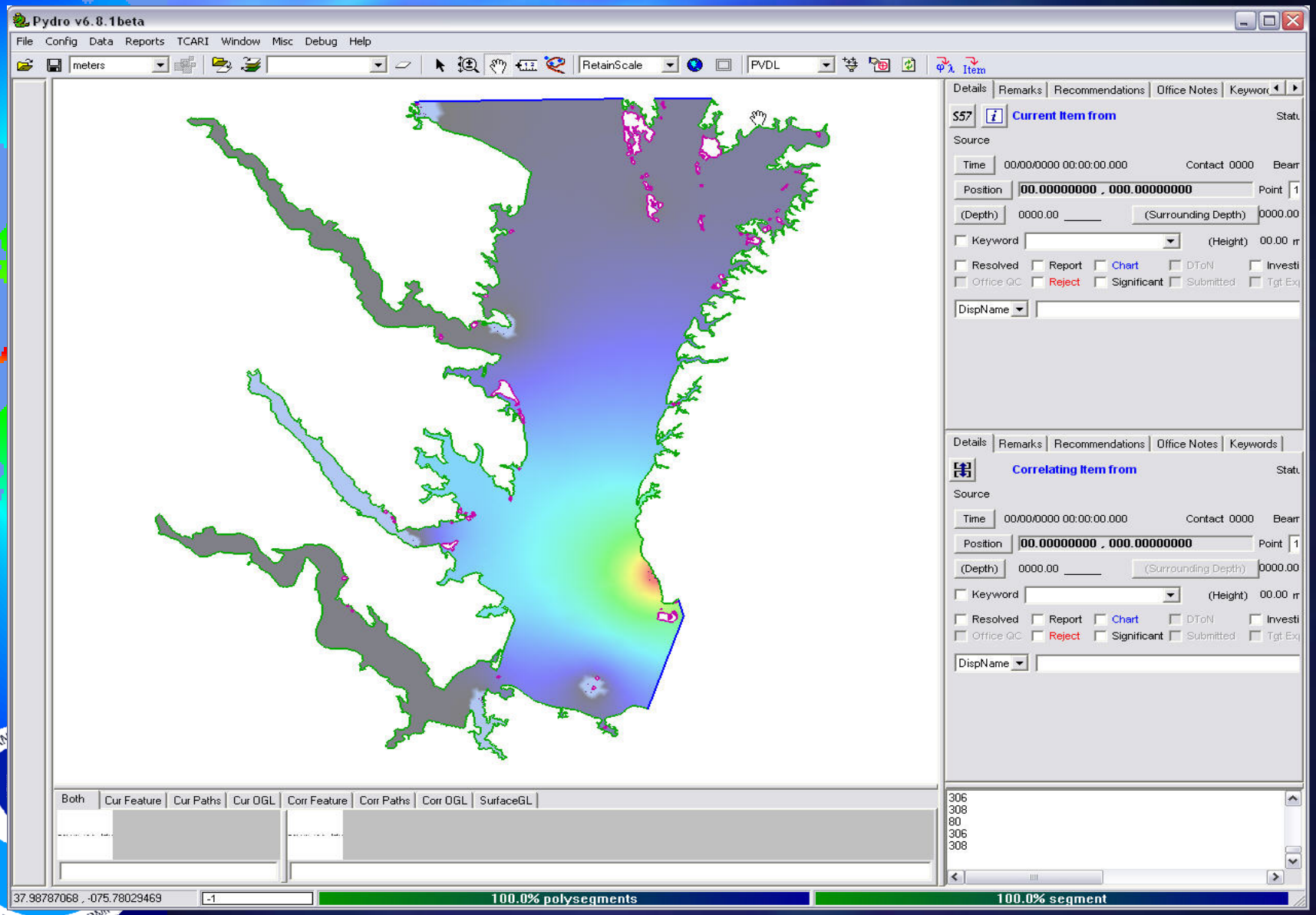
- Irregular mesh from Delauney triangulation.
- ~600 mesh nodes
- c.f. ~6000 grid cells
- resolution of coastline determines density of the grid



Generate the triangular mesh

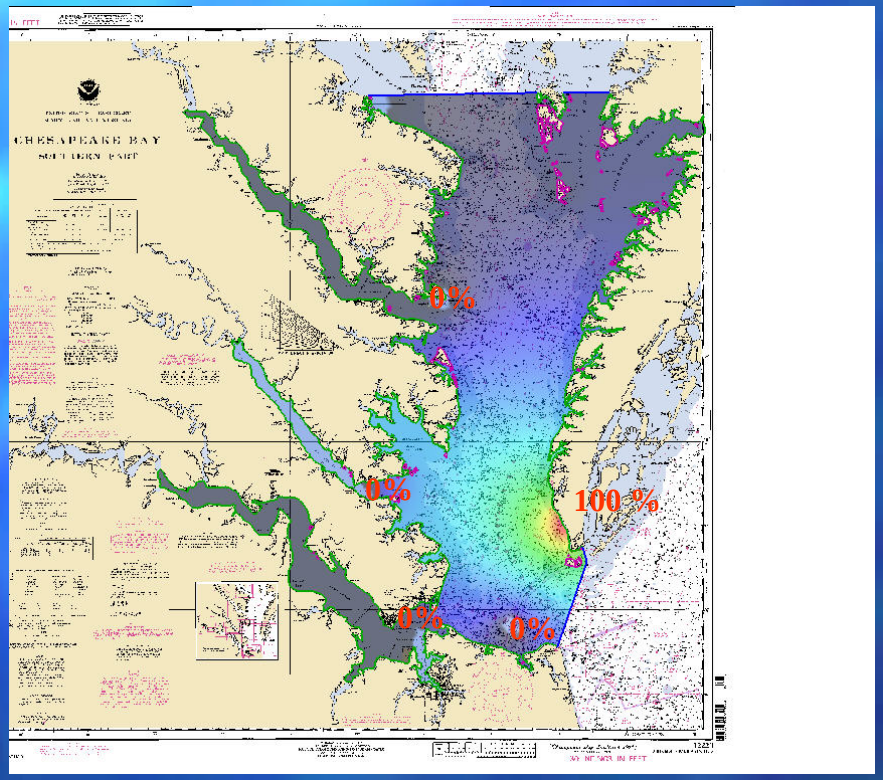


Load data and run TCARI interpolation



How TCARI Interpolates

Spatial Interpolation Using Weighting Functions

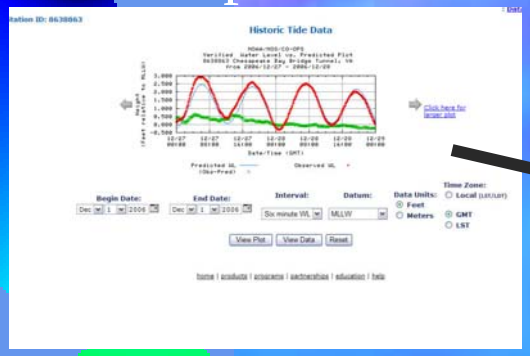


- Each grid point has a set of weighting values associated with it.
- Once these values are computed, they do not change, unless a new water level gauge is added, or if datums/HA are updated.
- The same grid can be used for multiple projects.

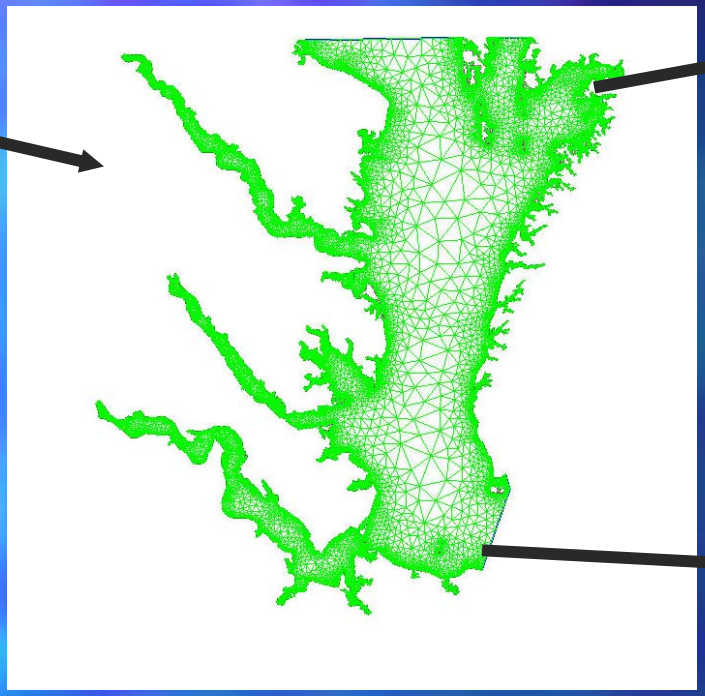
3 Sets of Weighting Values = Are Computed (Since each piece is interpolated separately)

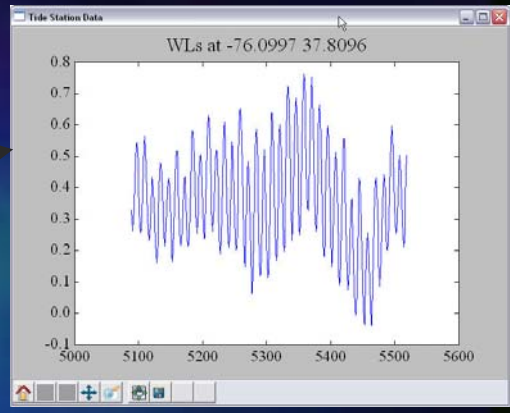
1) astronomical tide
2) residuals
3) datum offsets

Input

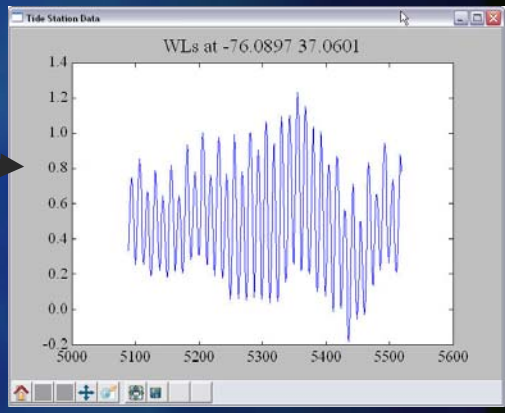


6 – Minute Water Level Data from CO-OPS webpage

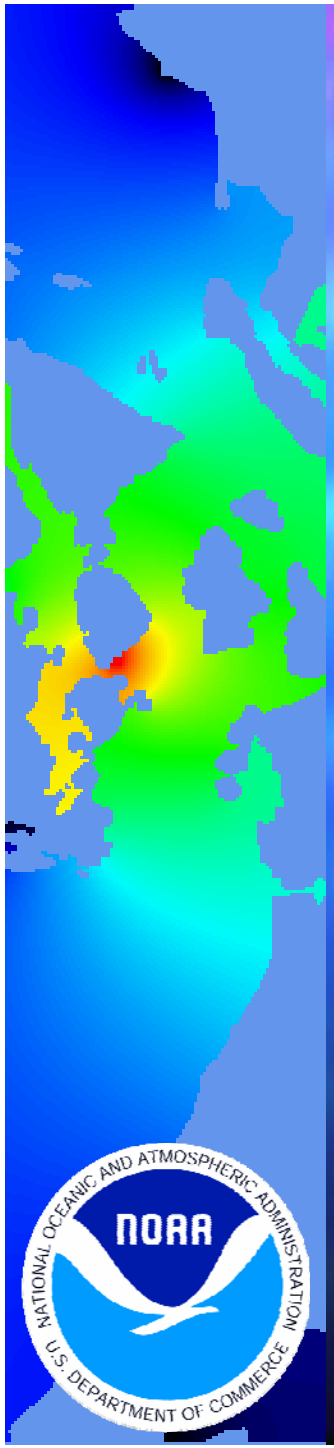




Output

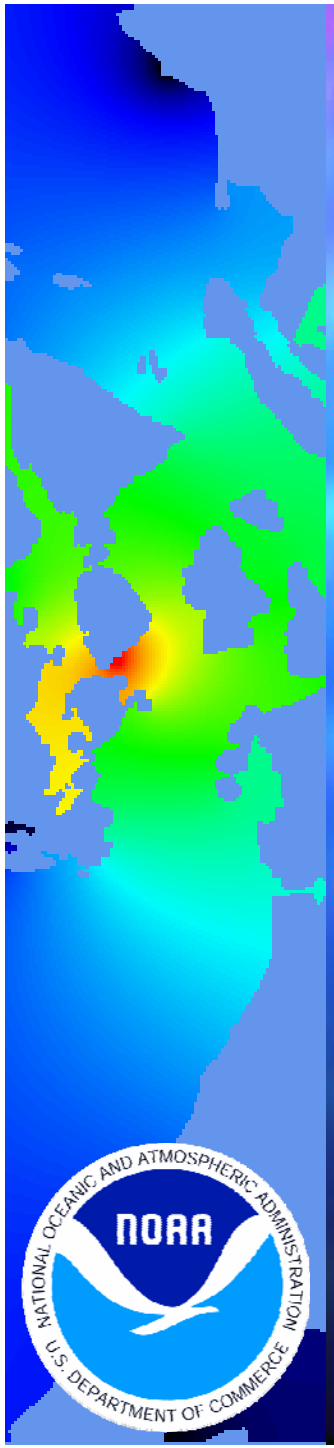


TCARI spatially interpolates the tidal and non-tidal (residual) components of the water level signal, generating a tide corrector at a specific location.



Expected Benefits

- Increased water level correction resolution.
- This method produces more realistic water level uncertainties which, in most cases, will be less than present water level uncertainties... reducing Total Propagated Error (TPE) of survey depths.
- Quantitative, automated method to account for spatial variability of water level corrections in hydrography.
- Eliminates time spent hand drawing co-tidal lines and polygons in MapInfo.
- Useful for other applications such as Restoration Projects and Photogrammetry.



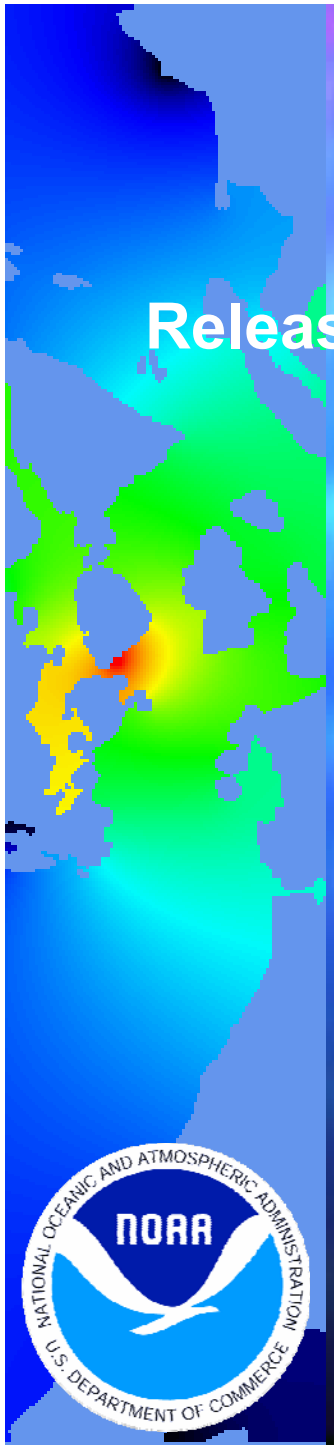
Constraints and Future Capabilities

Constraint

- TCARI requires tide gauge information. Older stations (before 1980's) are not readily available.

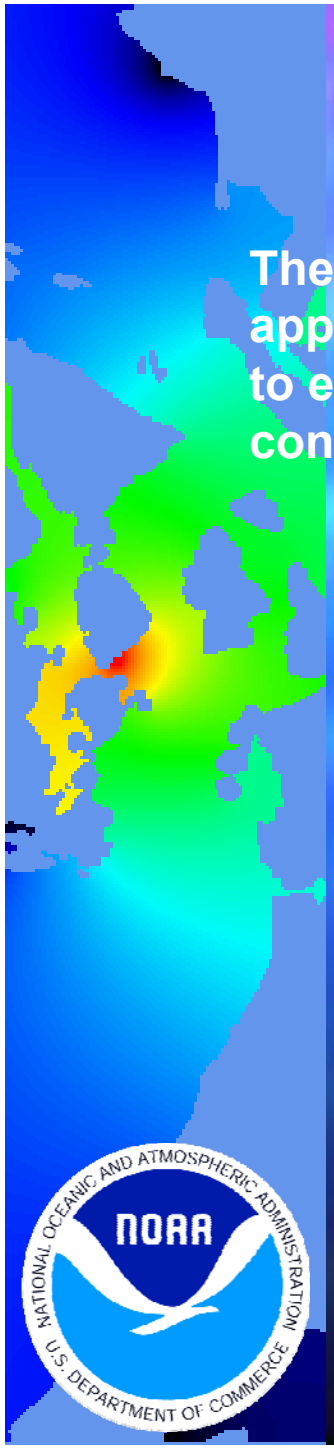
Future Capabilities

- Incorporate ADCERC offshore model



Release 1.0 of CO-OPS' electronic tide and tidal current prediction program called eTides

Expected release date in 2008



The main focus for this initial release is to develop a web-based application which will allow users, inside and outside of NOAA, to easily obtain accurate tide predictions in a form which is convenient for use.

- Map-based displays and text views for station selection

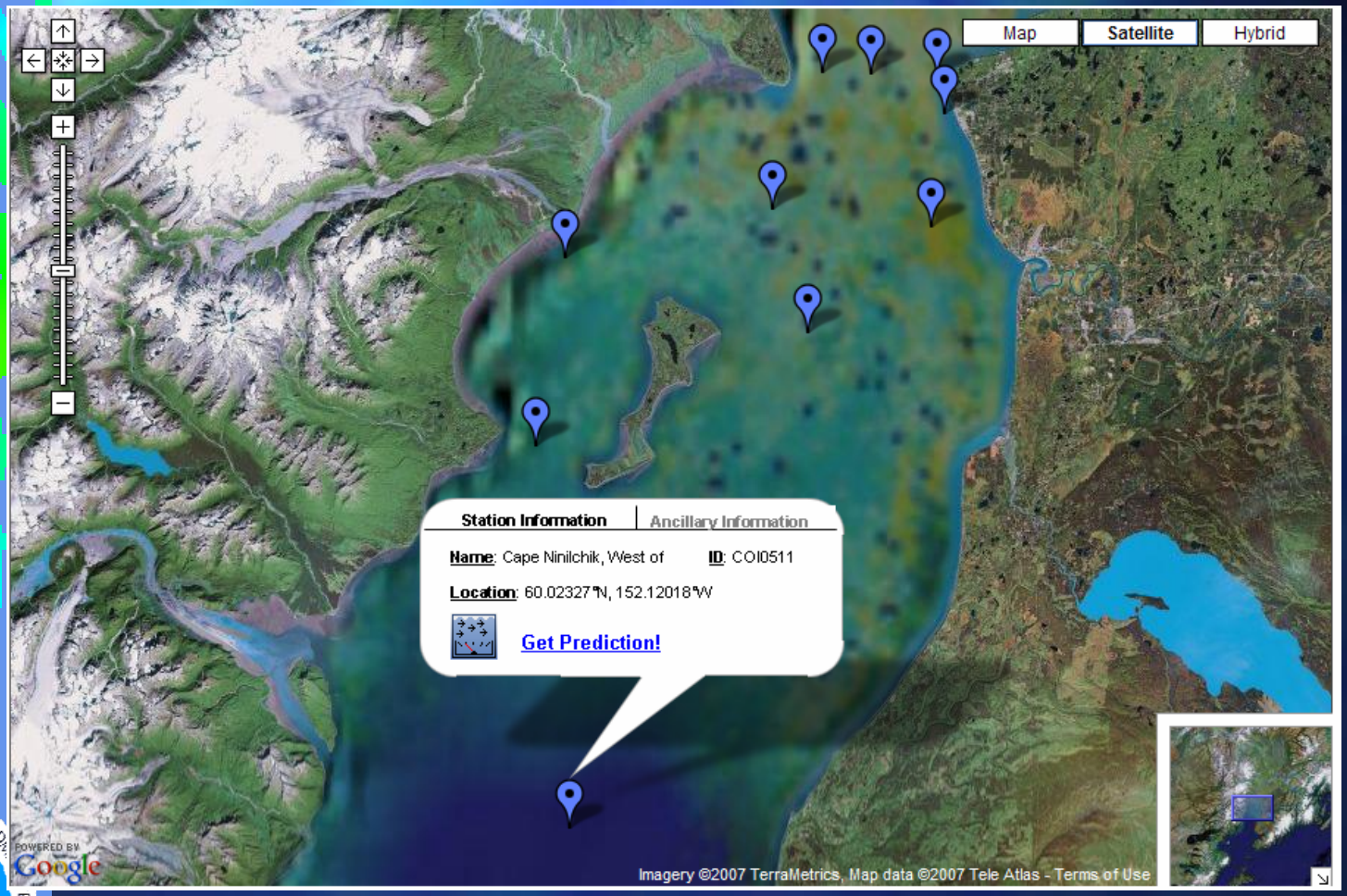
- “On-the-fly” predictions based on harmonic constituents where available

- Tabular and graphical displays of tide predictions for a user-specified time interval and datum

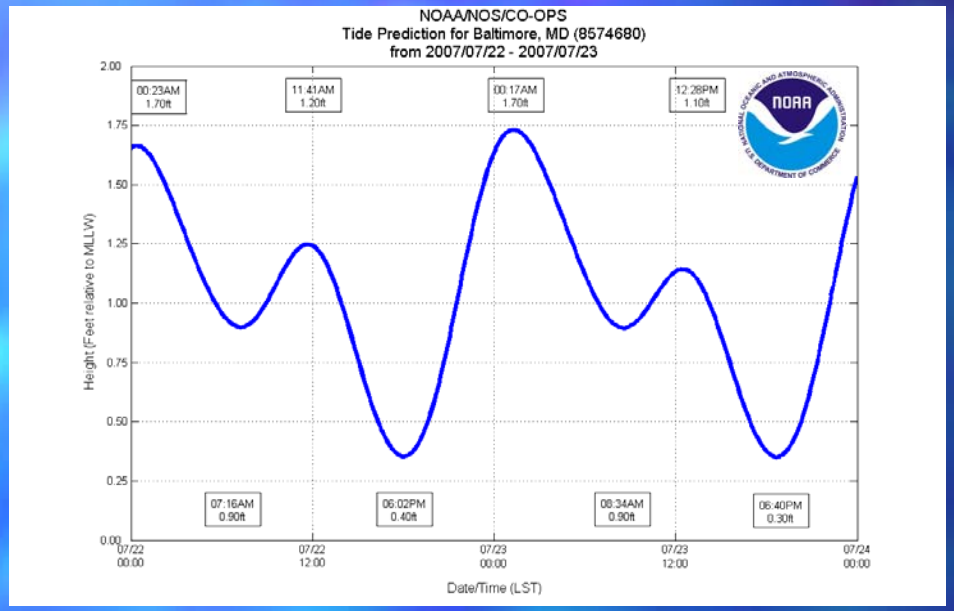
- Output options which will allow users to import the tide predictions into other tools

- Programmatic access to all predictions, constituents and updates via a web services portal

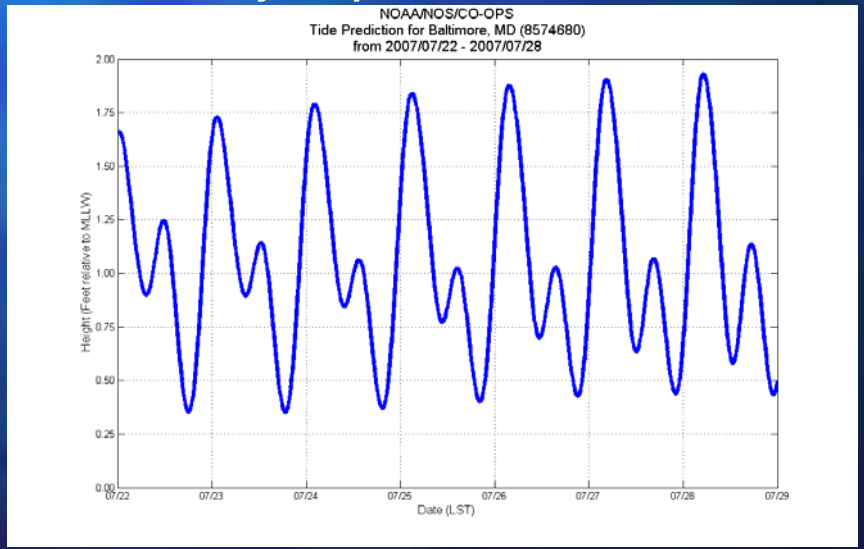
Station Selection Map Interface with Tiled Window



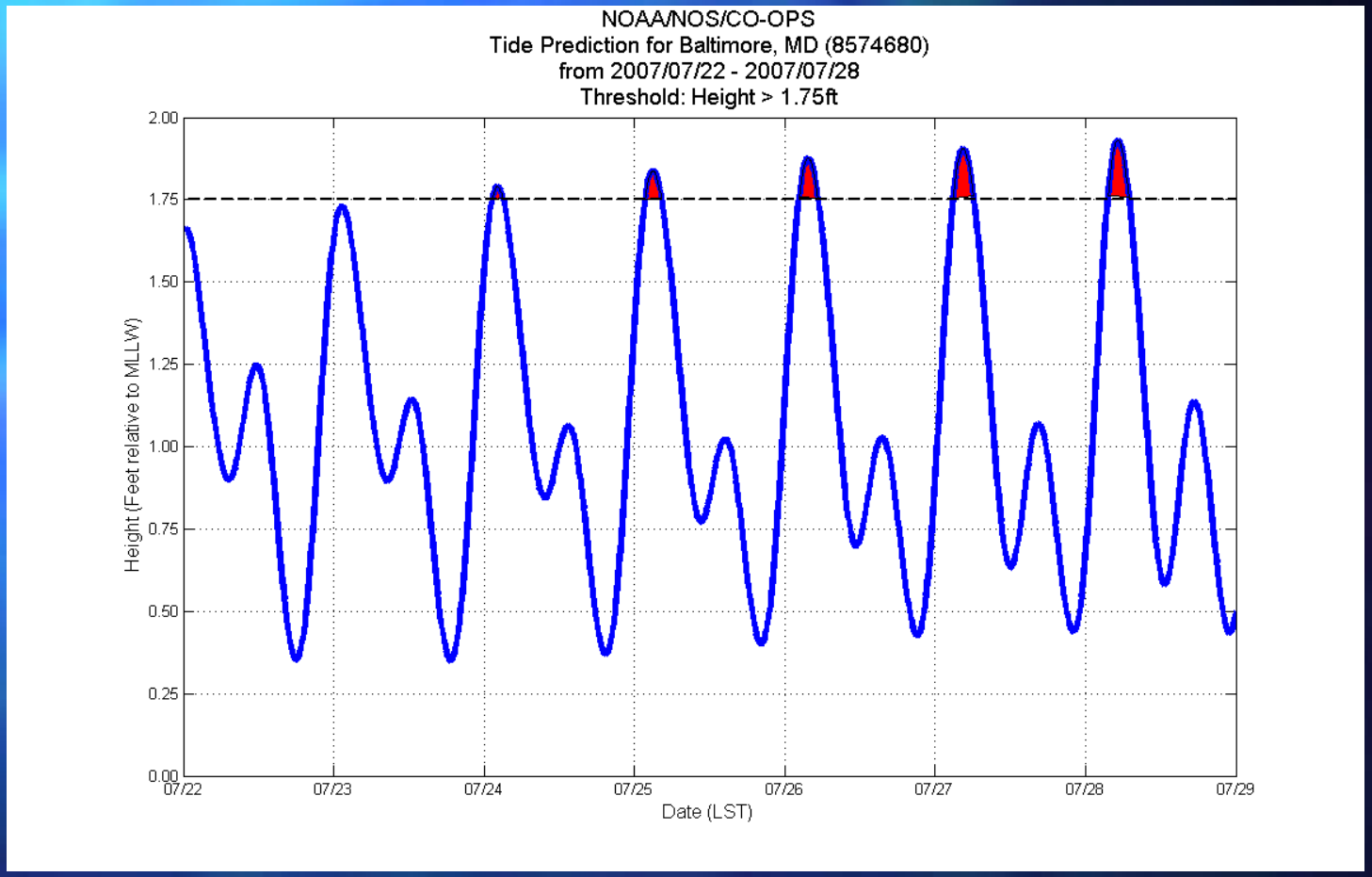
Daily Graphical Prediction



Weekly Graphical Prediction



Threshold Graphical Prediction



Monthly Graphical Prediction