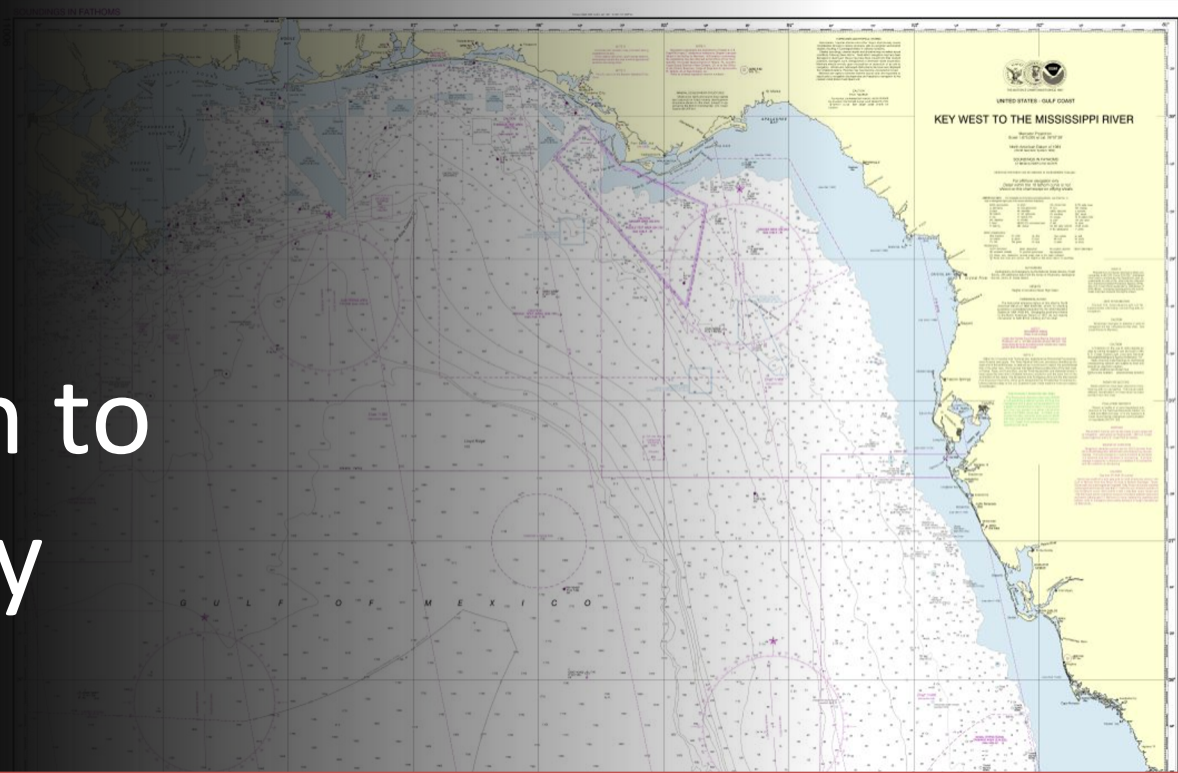


Introduction to Hydrography



Stephan D. Howden

The University of Southern Mississippi



Objectives



Introduce you to the profession of hydrography



Give you an appreciation for the importance of hydrography



Give you some resources to learn further

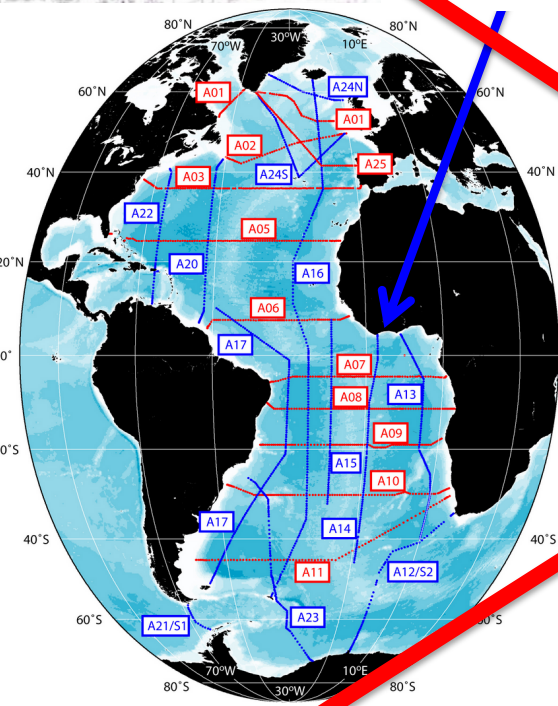
What is Hydrography?

UNITED STATES COAST AND GEODETIC SURVEY
KEY WEST WEST TO THE MISSISSIPPI RIVER

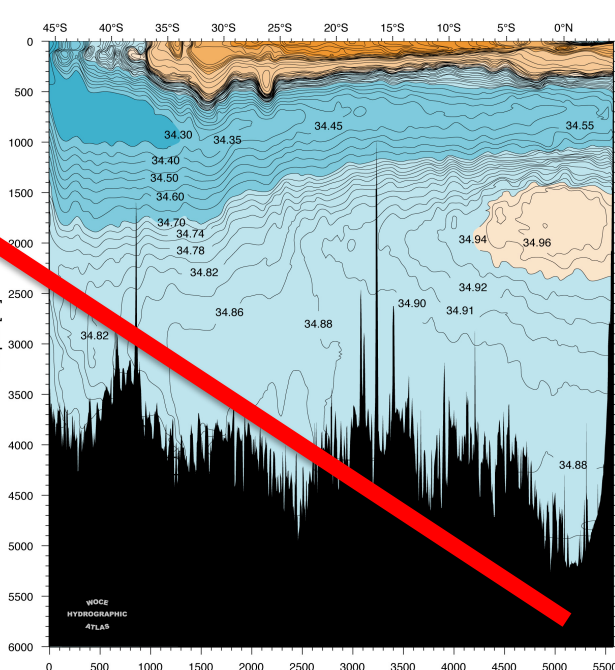
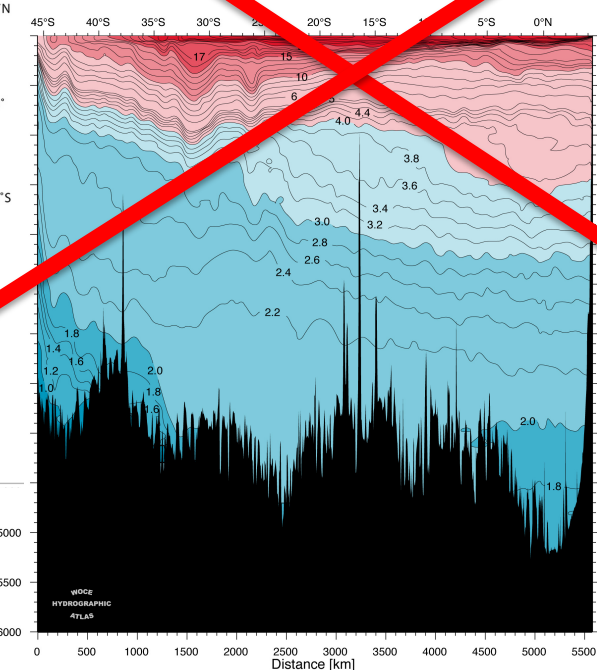
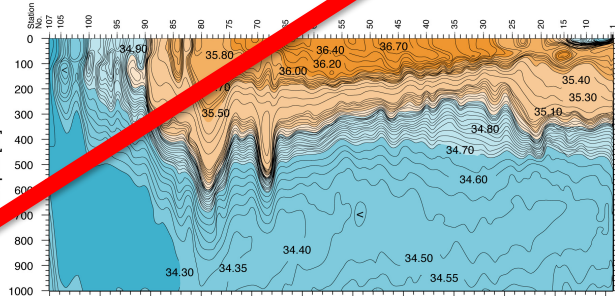
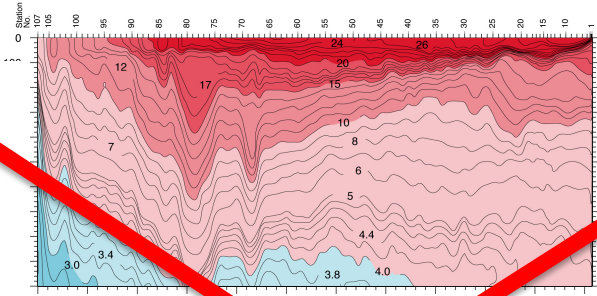
WOCE Section A14

Potential Temperature [°C] for A14 5°W

CTD Salinity for A14 5°W



© 2011 International WOCE Office





International Hydrographic Organization*



UNITED STATES - GULF COAST

KEY WEST TO THE MISSISSIPPI RIVER

Established in 1921

The intergovernmental consultative and technical organization to support safety of navigation and protection of marine environment

UN observer status

Recognized as the UN competent technical authority for hydrography and nautical charting.

* IHO Publication M-2

<https://iho.int>



What is Hydrography?

UNITED STATES - GULF COAST
KEY WEST WEST TO THE MISSISSIPPI RIVER

IHO Definition:

Hydrography is the branch of applied sciences which deals with the measurement and description of the physical features of oceans, seas, coastal areas, lakes and rivers, as well as with the prediction of their change over time, for the primary purpose of safety of navigation and in support of all other marine activities, including economic development, security and defense, scientific research, and environmental protection.

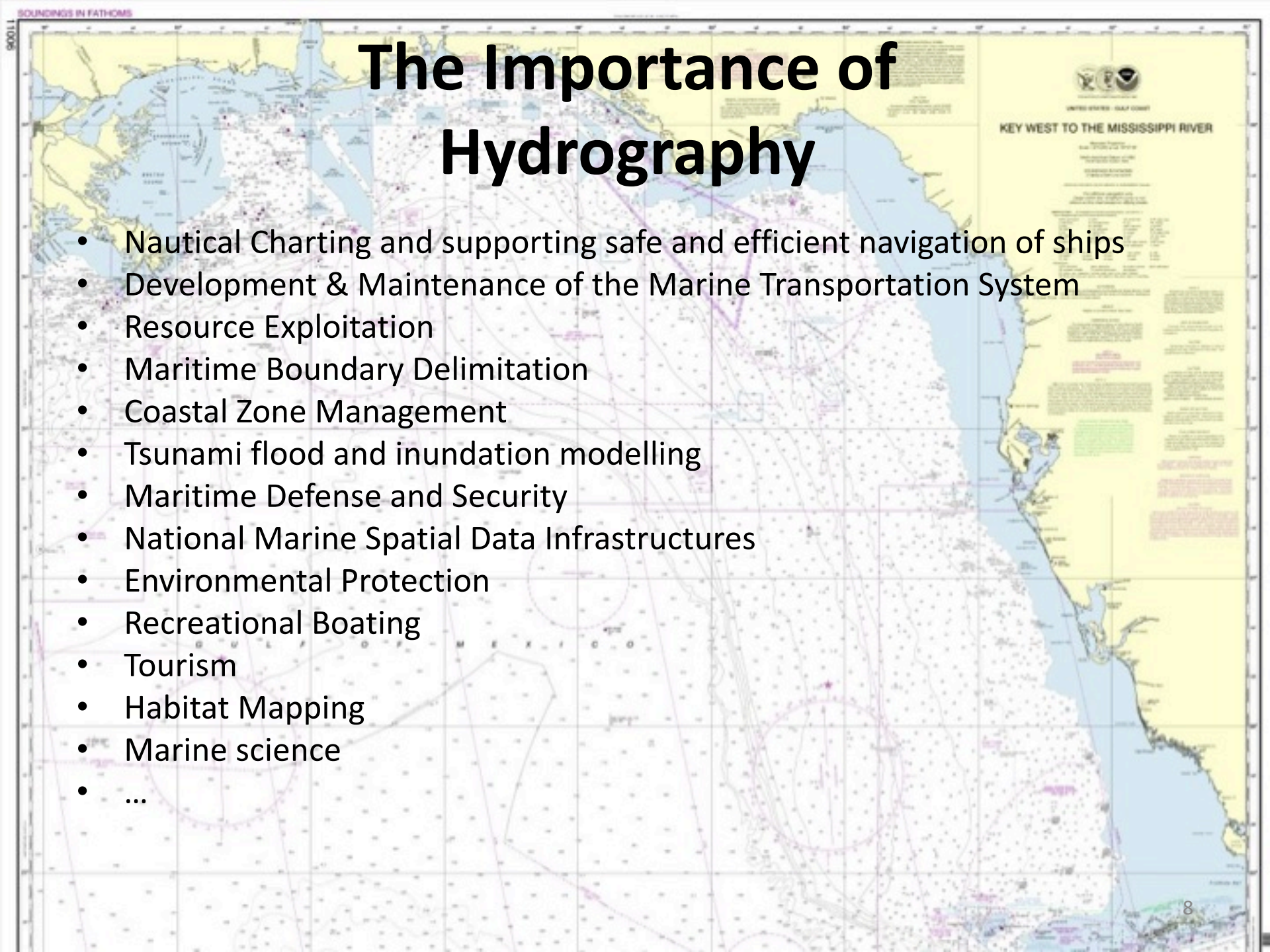


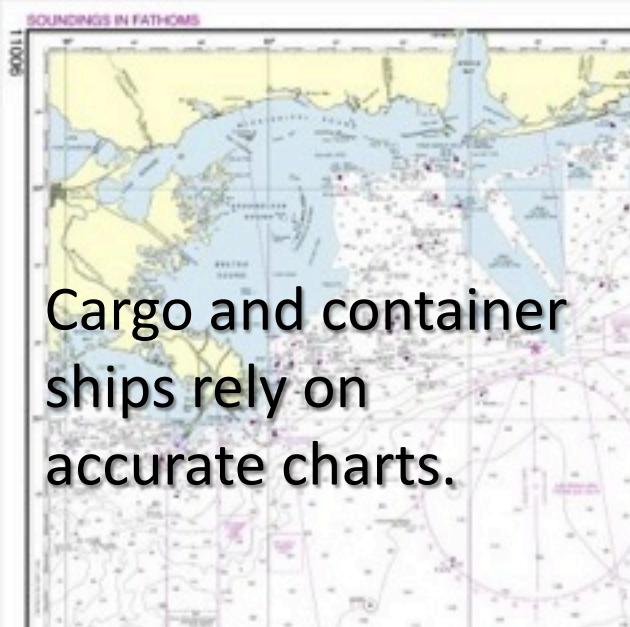
What Do Hydrographers Do?

- Survey the seafloor, lakes and river bottoms
- Survey the shoreline and structures of significance to navigation (e.g., bridges)
- Oceanographic measurements:
 - Water levels
 - Currents of significance to navigation
 - Sound speed profiles
 - Sediment samples,
 - Utilize information from water column acoustic backscatter
 - ...
- Create navigational charts
- ...

The Importance of Hydrography

- Nautical Charting and supporting safe and efficient navigation of ships
- Development & Maintenance of the Marine Transportation System
- Resource Exploitation
- Maritime Boundary Delimitation
- Coastal Zone Management
- Tsunami flood and inundation modelling
- Maritime Defense and Security
- National Marine Spatial Data Infrastructures
- Environmental Protection
- Recreational Boating
- Tourism
- Habitat Mapping
- Marine science
- ...





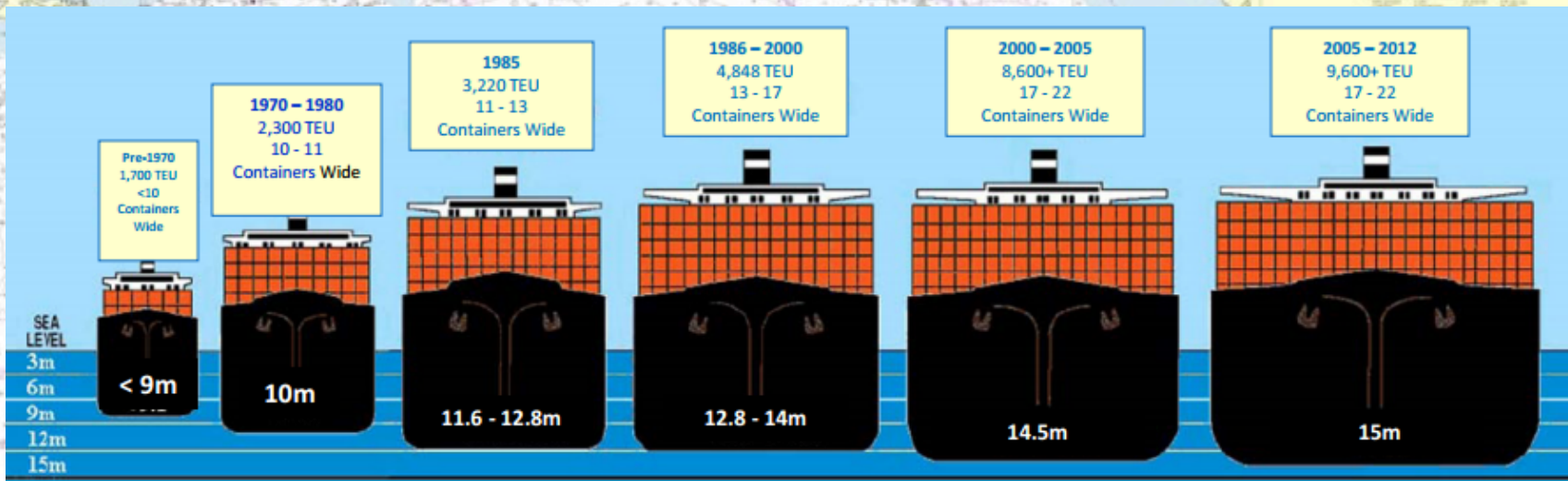
Cargo and container ships rely on accurate charts.



These ships move 95% of all international goods.

Navigating with Smaller Under Keel Clearances Makes Money

Each inch of draft can mean an extra \$5M of cargo can be loaded (NOAA/NOS)



Smaller under keel clearance requires more precise hydrographic data and real-time positioning



Uncharted waters: Mega cruise ships sail the Arctic: Crystal Serenity Cruise Ship Completes Historic Northwest Passage Arctic Journey – Sep 2016



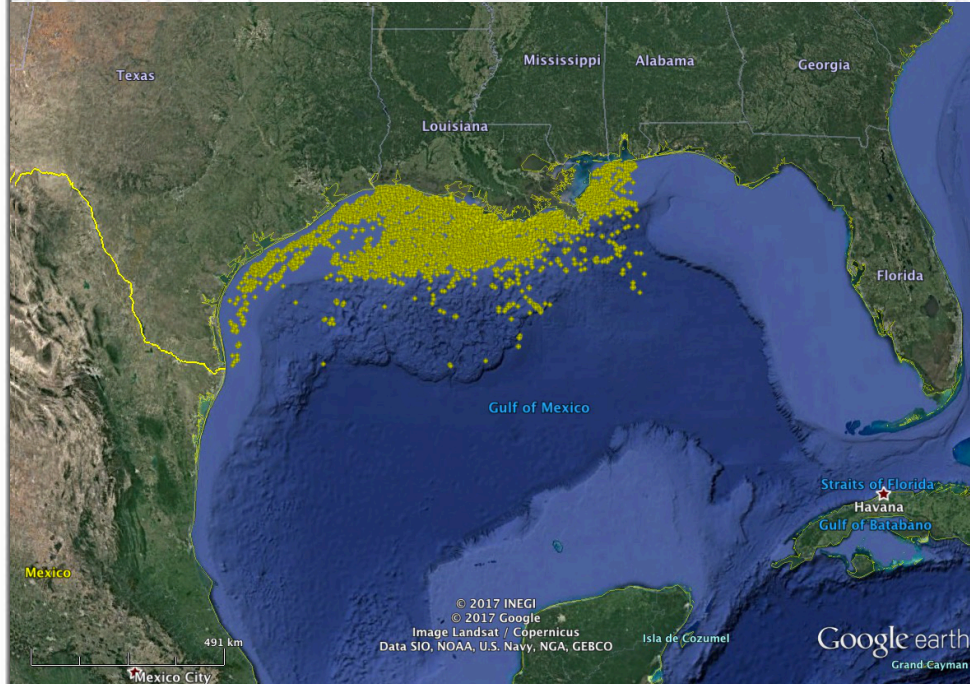
Viewed online 10/27/16
www.cruisecritic.com



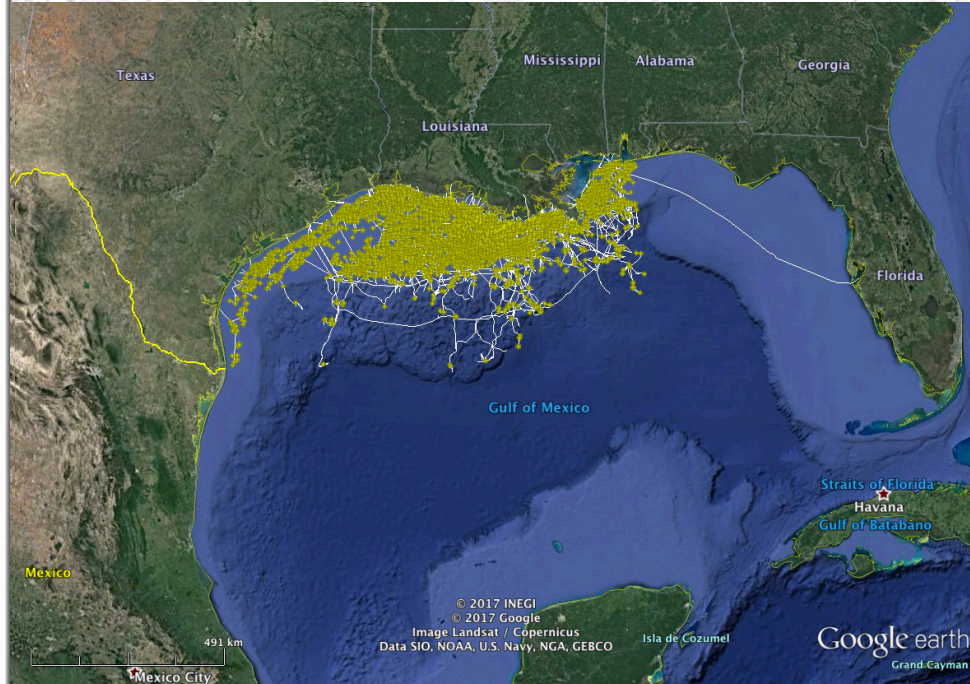
Resource Exploitation Oil/Gas



Resource Exploitation Oil/Gas



Resource Exploitation Oil/Gas





Resource Exploitation Offshore Wind Farms



Maritime Boundaries Delimitation

As summer arctic ice cover diminishes, seafloor resources become available and new shipping routes open up.

Global Warming Triggers an International Race for the Arctic

As the ice melts, national rivalries heat up over oil and gas deposits and shipping routes.

At the Top of the World

This summer saw the first-ever recorded opening of both potential Arctic Ocean routes—the Northwest Passage and the Northern Sea Route. The historic melting of the Arctic ice cap is likely to launch a new era of oil and gas exploration, shipping, tourism, and—perhaps—geopolitical rivalries.



By Thomas Omestad Oct. 9, 2008 [Leave a Comment](#) [SHARE](#)

How Best for Coastal and Offshore Aquaculture to Help Feed a Growing Population?

- Half all fish for human consumption now comes from aquaculture
- Food security for the growing world population will be significantly positively impacted by aquaculture

State of the Worlds Fisheries and Aquaculture 2016, Food and Agriculture Organization of the United Nations



NCCOS NATIONAL CENTERS FOR COASTAL OCEAN SCIENCE

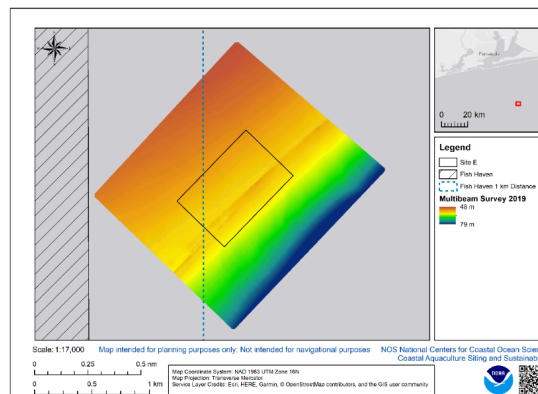
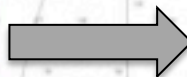
Preliminary Results Baseline Environmental Survey



Results of multibeam survey completed April 2019

- Surveyed 0.5 km beyond area of interest
- 2-m resolution
- Depths confirmed 55 m
- Minimal slope across site
- Small ridge detected
- Sand substrate

Hydrography provides baseline environmental data for aquaculture siting

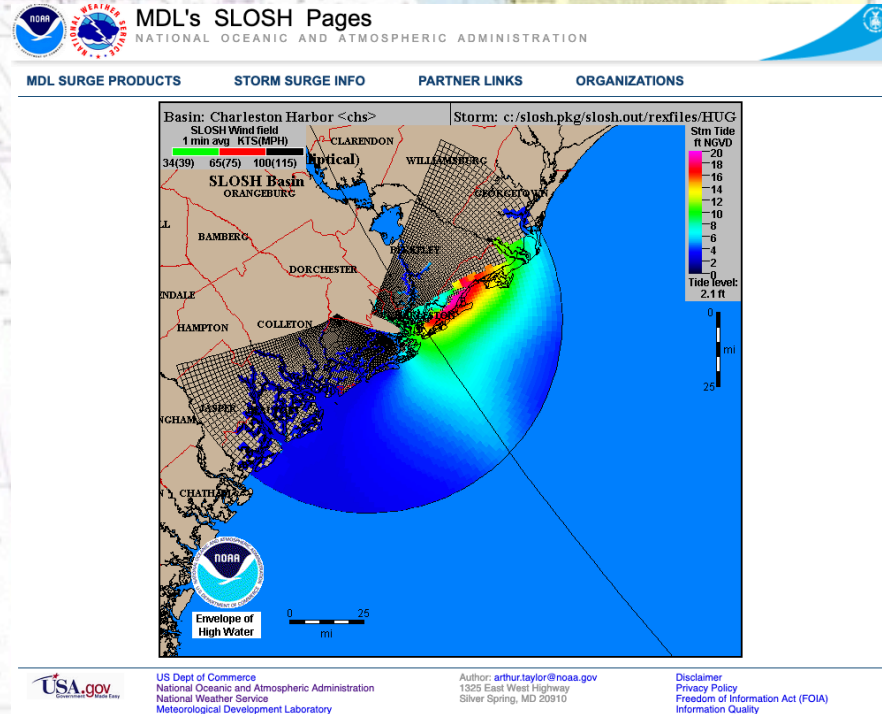
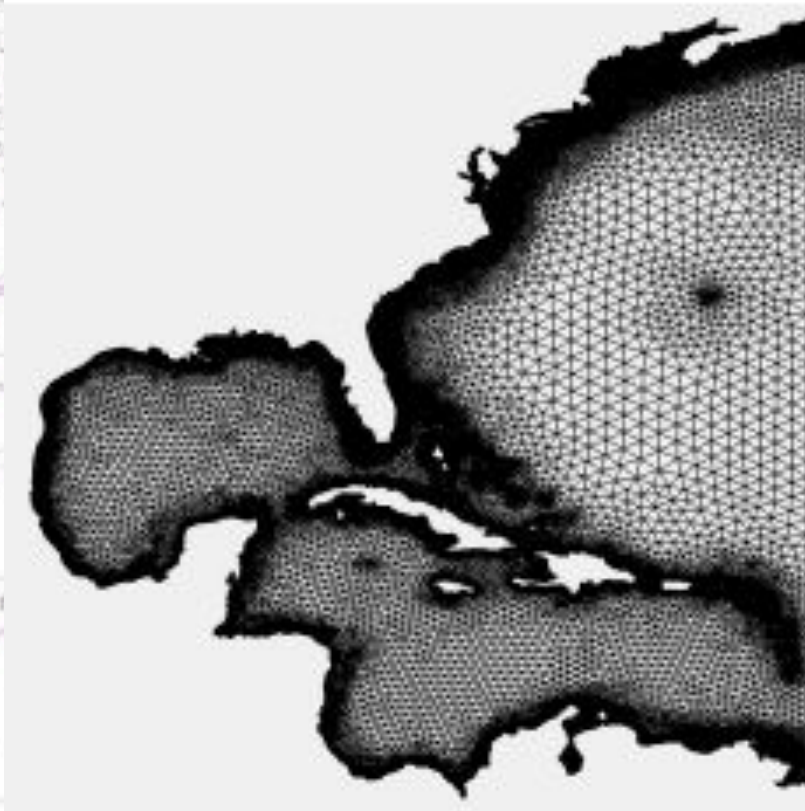


Side-scan and sub-bottom survey May 2019

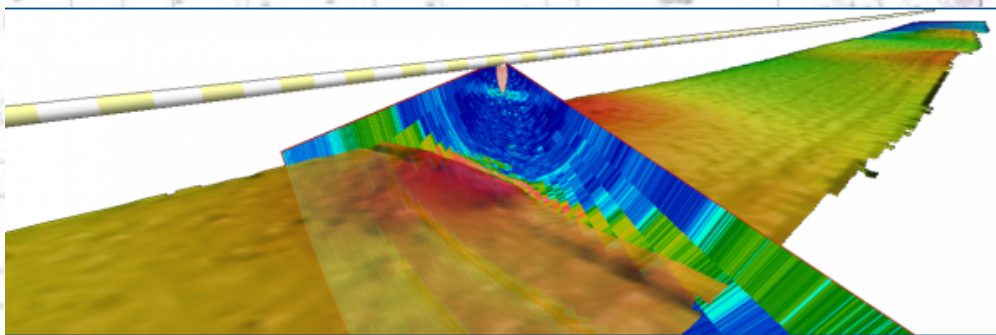
Accurate Bathymetry and Coastlines Crucial for Numerical Models

Model Grid Requires Depths
and Coastline

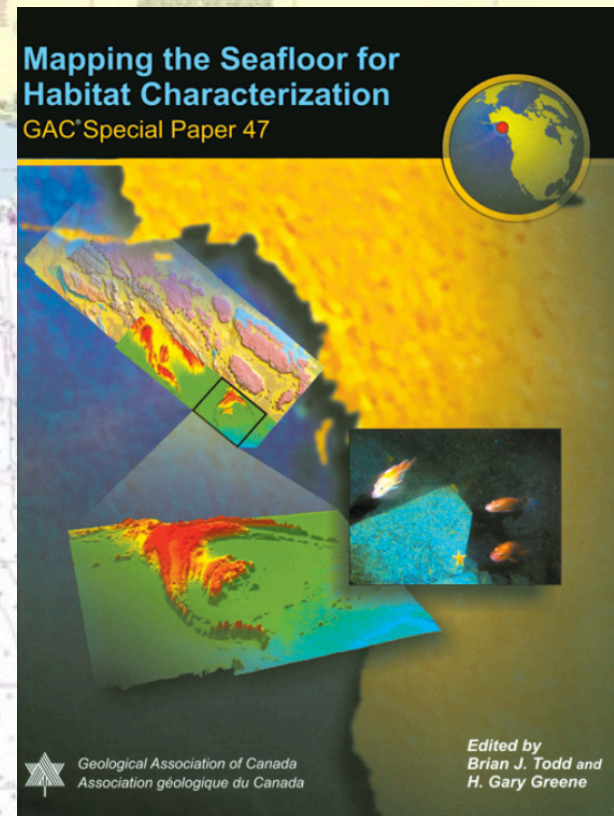
Example Model Storm Surge
Output



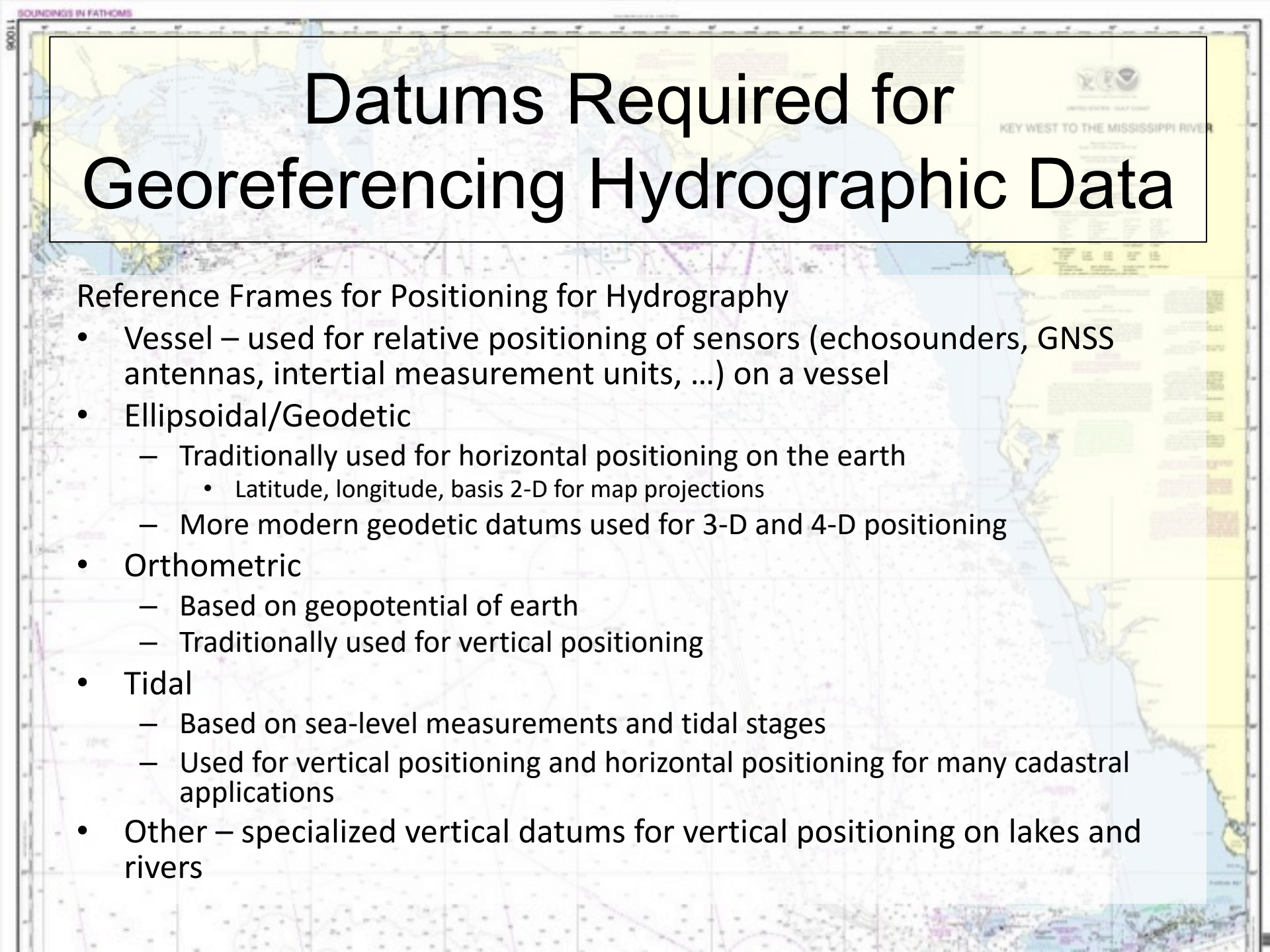
Water column acoustic backscatter gives information on water column constituents: density layers, zooplankton, fish, ...



University of New Hampshire Center for Coastal and Ocean Mapping



Seafloor acoustic backscatter gives information sediment and seafloor habitat



Datums Required for Georeferencing Hydrographic Data

Reference Frames for Positioning for Hydrography

- Vessel – used for relative positioning of sensors (echosounders, GNSS antennas, inertial measurement units, ...) on a vessel
- Ellipsoidal/Geodetic
 - Traditionally used for horizontal positioning on the earth
 - Latitude, longitude, basis 2-D for map projections
 - More modern geodetic datums used for 3-D and 4-D positioning
- Orthometric
 - Based on geopotential of earth
 - Traditionally used for vertical positioning
- Tidal
 - Based on sea-level measurements and tidal stages
 - Used for vertical positioning and horizontal positioning for many cadastral applications
- Other – specialized vertical datums for vertical positioning on lakes and rivers

Vessel Coordinate System

Determine a Vessel Frame of Reference for Instruments for Multibeam Adaptation and Geolocate Soundings

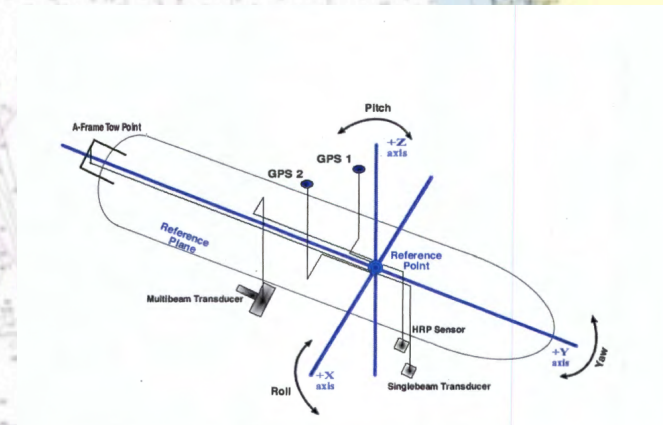
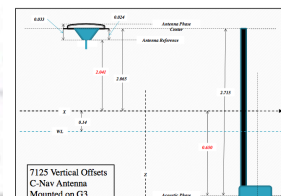
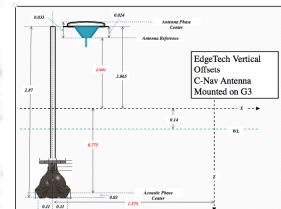
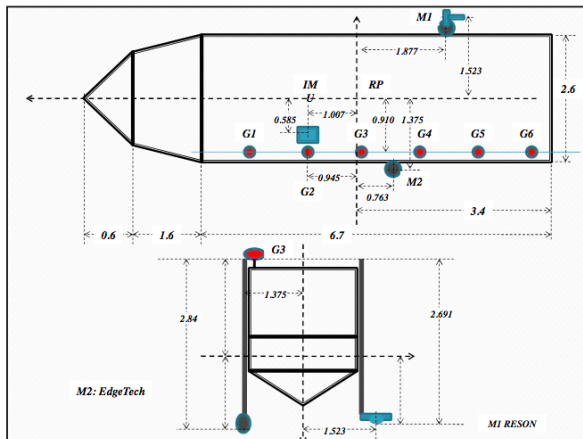
Surveying Vessel & Instrumentation



Survey Vessel



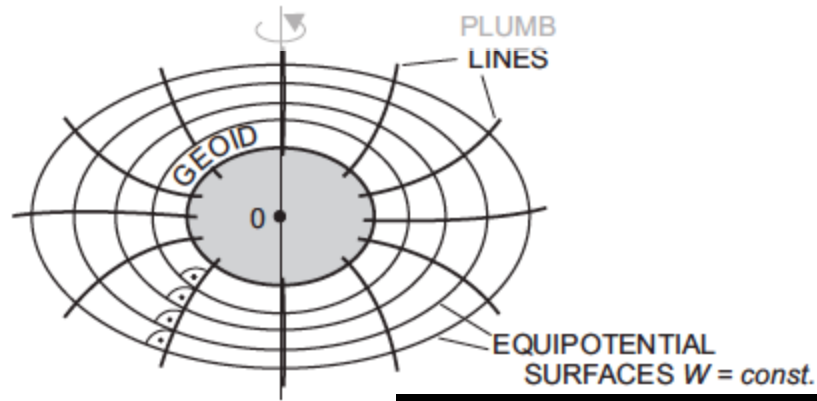
Vessel Coordinate System



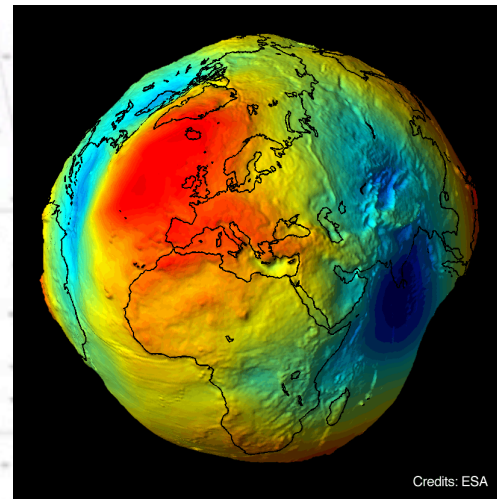
The Geoid

The Geoid- the equipotential surface of the geopotential that best fits global mean sea level (MSL).

- Would coincide with MSL if no forcing or geostrophic balance



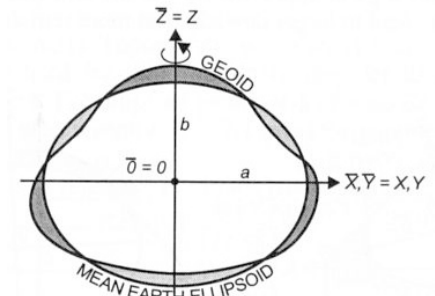
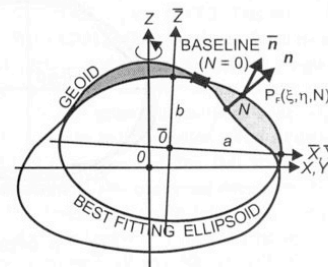
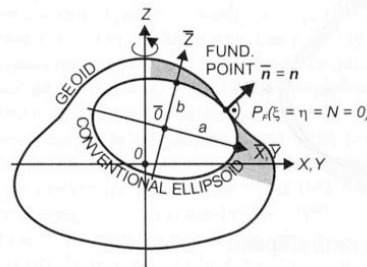
Modern geoid from earth gravity model (European Space Agency) with exaggerated relief from the ellipsoid



Horizontal/3-D Datums: Geodetic Datums

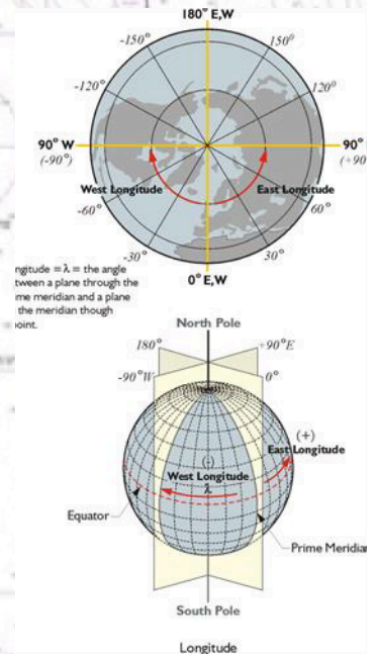
Historical: Best Fit to National or Regional Survey Network/Geoid

Modern: Best Fit to Global Geoid



Source: Torge (2011).

Horizontal positioning (latitude and longitude) of vessel and soundings, and vertical positioning of soundings for Ellipsoidally Referenced Surveys (ERS).

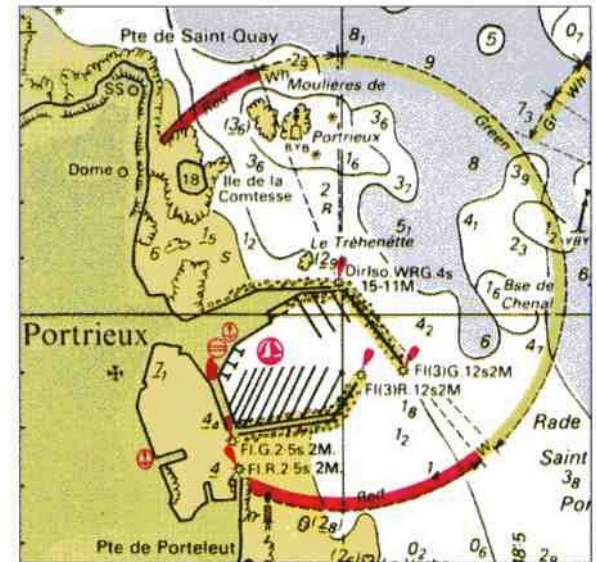


Modern Geodetic Datums Used in Africa:

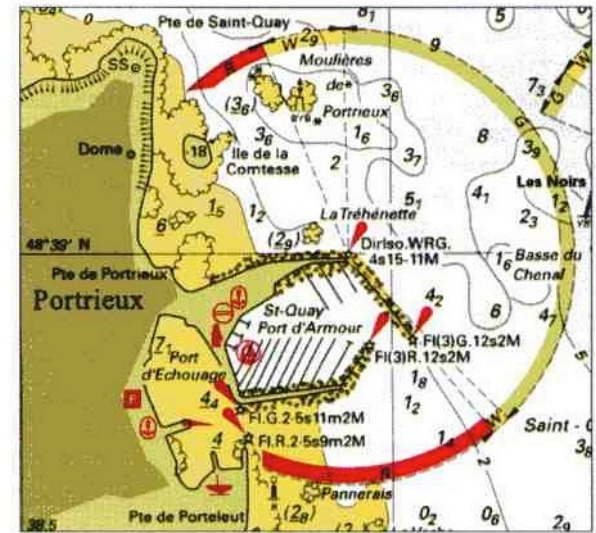
- World Geodetic System 1984
- African Geodetic Reference Frame

Different Geodetic Datums, Different Latitude and Longitude

Two recent chart editions, two different datums: European Datum (ED 1950) and WGS84.



Not to be used for navigation



Not to be used for navigation

Orthometric Datums

The Geoid- the equipotential surface of the geopotential that best fits global mean sea level (MSL).

- Would coincide with MSL if no forcing or geostrophic balance

Orthometric Height – height above the geoid following a vertical tangent path to the gravity vectors - commonly used for terrestrial elevations

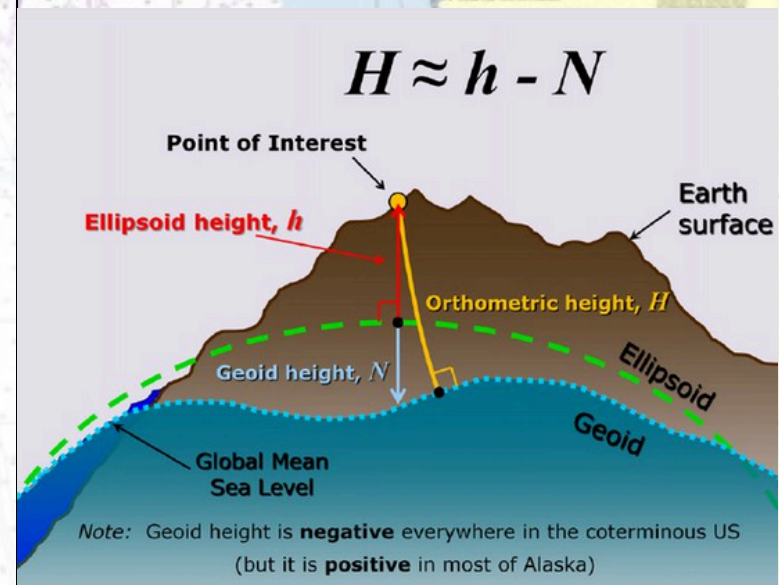
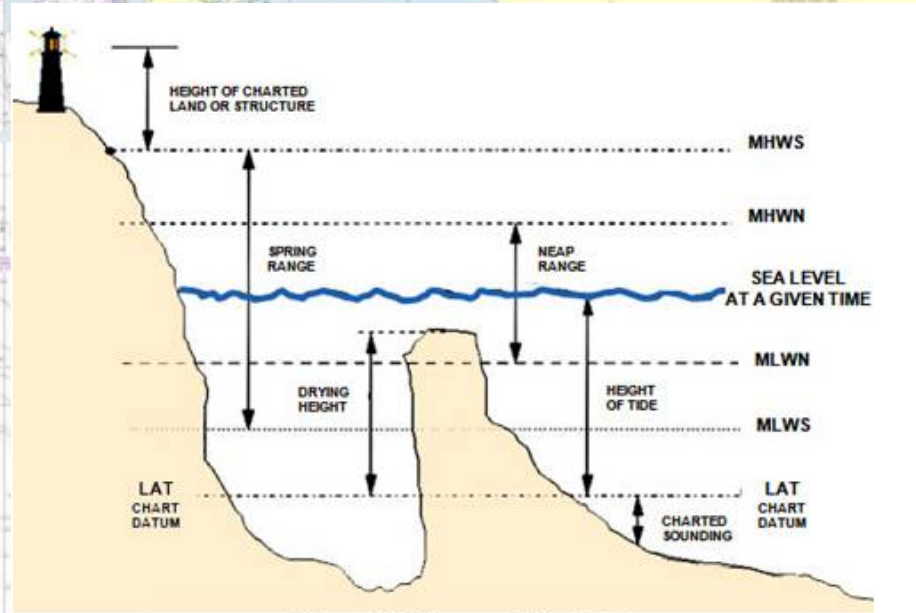


Figure Source: Richard Snay

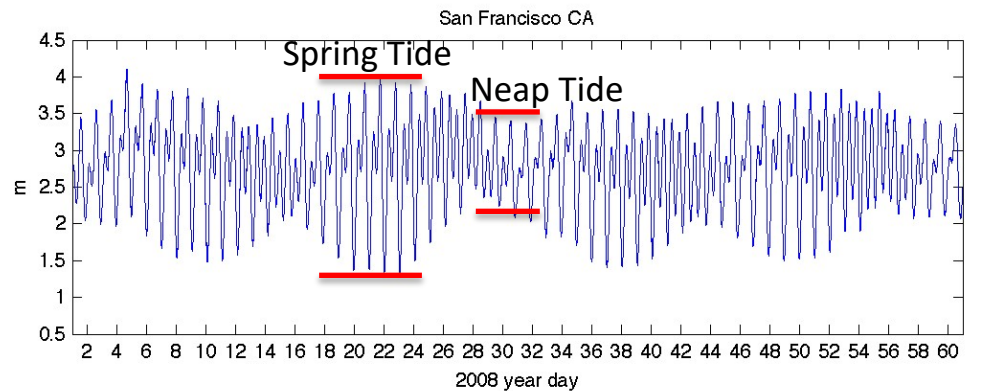
Tidal Datums

There are many different tidal datums defined over particular time periods, or epochs. Examples:

- Mean Sea Level: arithmetic mean of hourly heights
- Mean High Water: average of all high water heights
- Mean Low Water: average of all low water heights observed over the NTDE.
- Mean Lower Low Water: average of the lower low water heights
- Mean Low Water Springs: average of low waters during spring tide
- Lowest Astronomic Tide: Lowest tide level from harmonic analysis



Vertical datums for soundings (“chart datum”) and overhead obstructions are tidal datums. IHO recommends Lowest Astronomic Tide (LAT) for chart datum.



A nautical chart of the Gulf of Mexico and Caribbean Sea, showing depth soundings, navigational aids, and coastlines. The chart is titled "KEY WEST TO THE MISSISSIPPI RIVER" and includes various navigational information such as tide tables and a list of lights.

Chart Datums

Examples

- Lowest Astronomic Tide
 - Recommended by the IHO
 - Lowest predicted tide from harmonic analysis
- Mean Low Water Springs
- Mean Lower Low Water

A nautical chart of the Mississippi River delta region, showing the river's path into the Gulf of Mexico. The chart includes depth soundings, navigational markers, and a grid. The text 'SOUNDINGS IN FATHOMS' is visible at the top left, and 'MISSISSIPPI RIVER' is visible on the right side. The title 'Tidal Datums Require Tide Gauges' is overlaid in large black font at the top center.

Tidal Datums Require Tide Gauges

- There are national and international networks of long-term tide gauges that serve as primary gauges for hydrographic surveying
- If more tide gauges are required for a hydrographic survey then secondary stations are installed for the length of the survey, but not less than 30 days.
- In some cases known tidal harmonic constituents and/or modeling are used to obtain chart datum.

International Sea-Level Data Centers

Global Sea Level Observing Center (GLOSS)

<https://www.gloss-sealevel.org/>

Permanent Service for Mean Sea Level (PSMSL):

<https://www.psmsl.org/>

University of Hawaii Sea Level Center:

<http://uhslc.soest.hawaii.edu>

British Oceanographic Data Centre

<https://www.bodc.ac.uk/>

Sea Level Station Monitoring

<http://www.ioc-sealevelmonitoring.org/>

GLOSS Data

GLOSS sea level data centres

Organisation	Geographical area	Data updates
Fast tide	Flanders Marine Institute (VLIZ), Belgium	Play and download of raw data
Fast mode	Permanent Service for Mean Sea Level (PSMSL), USA	Play and download of raw data from ingesters
Delayed mode	British Oceanographic Data Centre (BODC), UK	Final high tide gauge data from ingesters
Monthly averages	Permanent Service for Mean Sea Level (PSMSL), UK	Final monthly averages from ingesters
Coordinates and land motion	University of Colorado at Boulder Sea Level Center (COUSLC), USA	Final monthly averages from ingesters
	University of Colorado at Boulder Sea Level Center (COUSLC), USA	Final monthly averages from ingesters
	University of Colorado at Boulder Sea Level Center (COUSLC), USA	Final monthly averages from ingesters

British Oceanographic Data Centre
National Oceanography Centre

Marine data sharing and preservation, managed & operated by the National Oceanography Centre

Search our marine data →

PSMSL Permanent Service for Mean Sea Level

About Us | Data | Products | GLOSS | Training | Links

Welcome to the Permanent Service for Mean Sea Level (PSMSL)

Help us rescue tide gauge data from the 19th century!

PSMSL is the global data bank for long term sea level change information from tide gauges and bottom pressure recorders.

Products: Show the data set via Google Earth or obtain raw data products. View regional commentaries and action notices.

Training & Information: A wide variety of FAQs, training and software documentation, information on non-oceanographic signals in tide gauge records (e.g., glacial isostatic adjustment, atmospheric pressure, etc.)

SEA LEVEL STATION MONITORING FACILITY

IOC | Data | Products | GLOSS | Training | Links

Map-Based Data Page

Map-Based Data Page

Map-Based Data Page

UNIVERSITY OF HAWAII SEA LEVEL CENTER

Data | Network | Research | Products | GLOSS | About | Q

Recent Sea Level Trends

Last 10 years | Last 20 years | 1993-present | Submit global

Sea level trends (2010-2019)

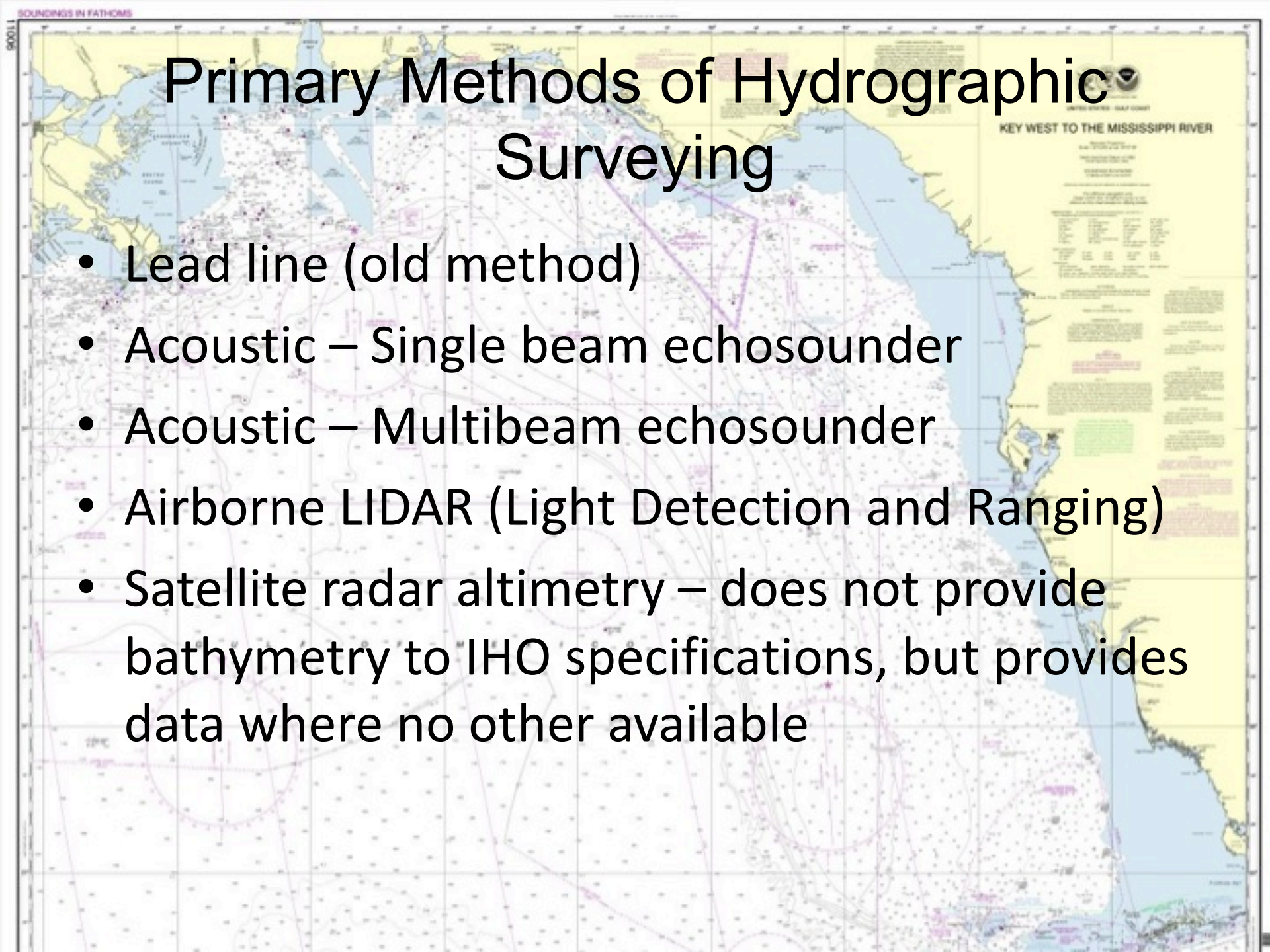
The rate of sea level change differs from one place to another and from one decade to the next. Click the tabs above the map to see trends over the last 10 years, the last 20 years, and since the beginning of the satellite record in 1993. The map shows sea level trends from satellite altimetry (coastal continents) and tide gauges (oceans).

The satellite trends reflect changes in the sea surface height only, with most of the spatial variation resulting from the influence of winds blowing over the ocean. The tide gauge trends are relative to a fixed point on land and reflect changes in water level plus local vertical land motion. The land rise or fall gauges can move up and down for a variety of reasons, such as subsidence or groundwater withdrawal.

Data sources: Trends were calculated using (1) tide gauge data from the IAGLR's Fast Delivery Database, and (2) SeaView altimeter products that were processed and distributed by the E.U. Copernicus Marine and Environment Monitoring Service (CMEMS). The color scale indicates the 95% confidence interval for the trends determined by Aoste. *Please use these accurate 5-yearly changes reported from the above eqns.***

Secondary Gauge Installation for a Hydrographic Survey

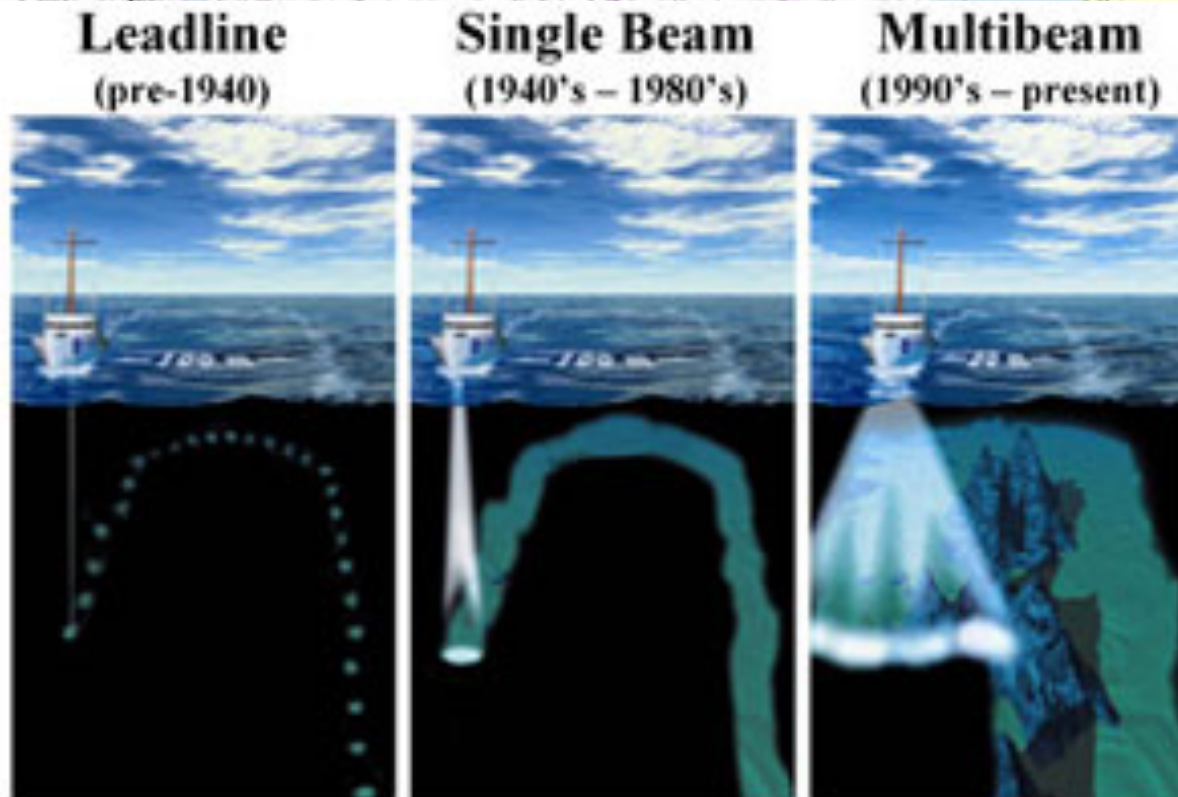


A nautical chart of the Gulf of Mexico and Caribbean Sea, showing depth soundings, navigational aids, and a grid. The chart is titled 'KEY WEST TO THE MISSISSIPPI RIVER' and includes a NOAA logo. The text 'SOUNDINGS IN FATHOMS' is visible in the top left corner. The chart shows the Gulf of Mexico to the west and the Caribbean Sea to the east, with the Gulf of Mexico being the primary focus of the surveying methods listed.

Primary Methods of Hydrographic Surveying

- Lead line (old method)
- Acoustic – Single beam echosounder
- Acoustic – Multibeam echosounder
- Airborne LIDAR (Light Detection and Ranging)
- Satellite radar altimetry – does not provide bathymetry to IHO specifications, but provides data where no other available

Mapping the Seafloor From Leadline to Multibeam

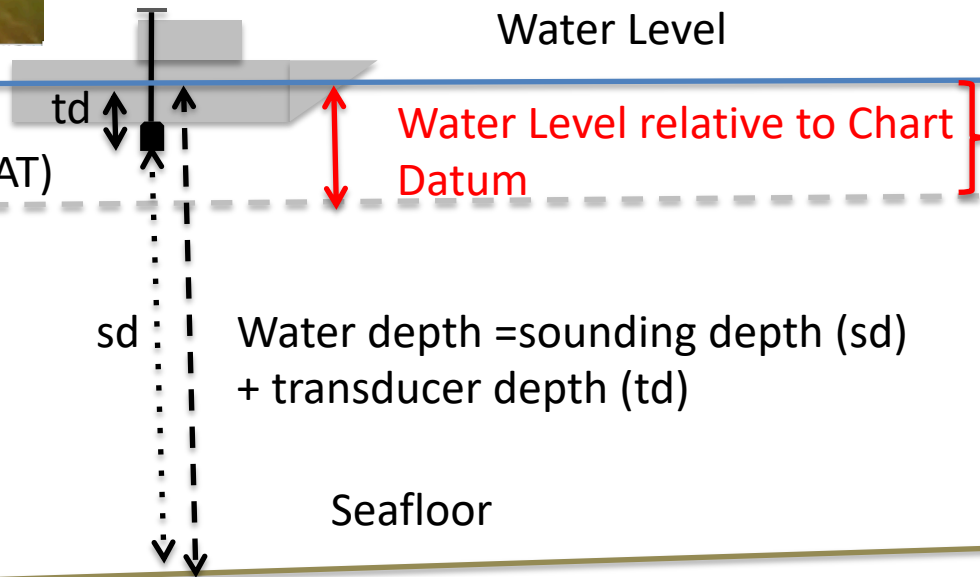


Depth from acoustic two-way
travel time

Multibeam Surveying



Mapping of Seafloor & Sounding Reduction: Traditional Survey



Crucial Information:
Tide gauges
& Tidal
Zoning

Other Complicating Factors

- Vessel Heave
 - mitigate with low pass filter
- Vessel Pitch and Roll
 - Measure and remove if necessary
 - Multibeam system can remove through beam forming
- Vessel Squat
 - Measure and remove if necessary
- Vessel Dynamic Draft
 - Measure and remove if necessary
- Sound speed variations and refraction
 - Measure sound speed profiles

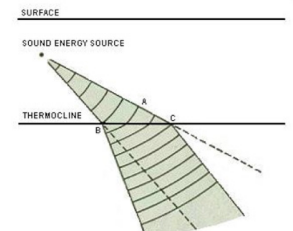
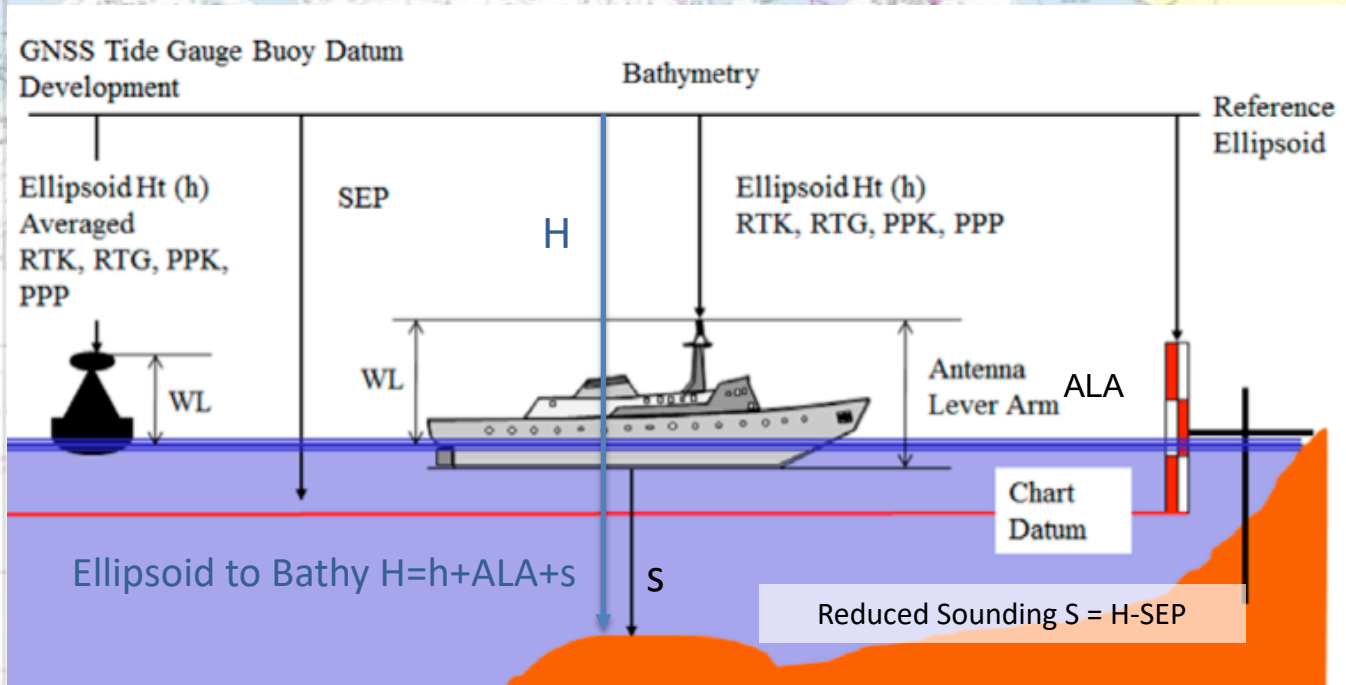


Figure 4.7: Sonar refraction due to thermocline.

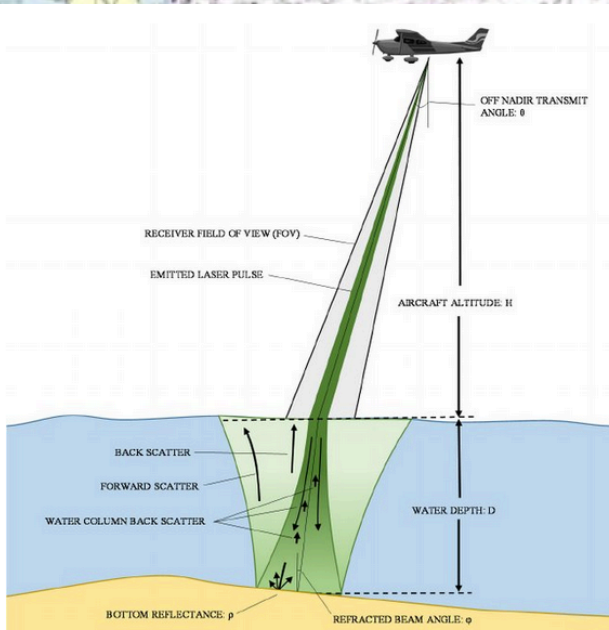
Ellipsoidally Referenced Survey

Decoupling Tides from Hydrographic Surveying

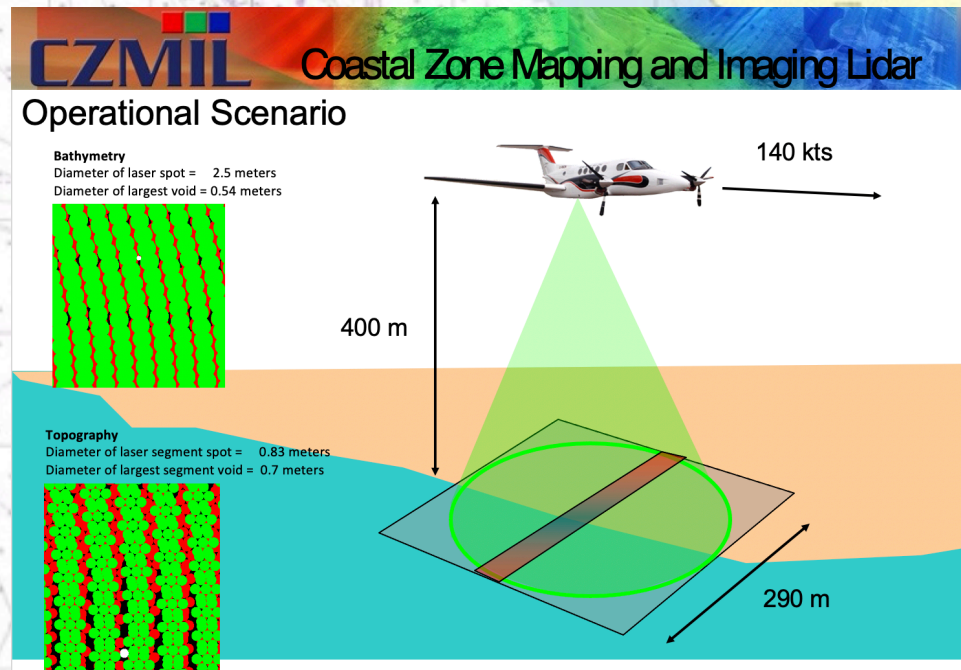


- Water depths are measured to the reference ellipsoid
- The separation between the ellipsoid and chart datum (“separation model”) may be determined by others (e.g., NOAA in the United States)
- The separation model is used to convert, or reduce, the water depths to chart datum.
- Heave, dynamic draft, squat and water level above chart datum not needed

Mapping the Seafloor From Airborne LIDAR



Kashani, A. G., Olsen, M. J., Parrish, C. E., & Wilson, N. (2015). A review of LiDAR radiometric processing: From ad hoc intensity correction to rigorous radiometric calibration. *Sensors*, 15(11), 28099-28128.



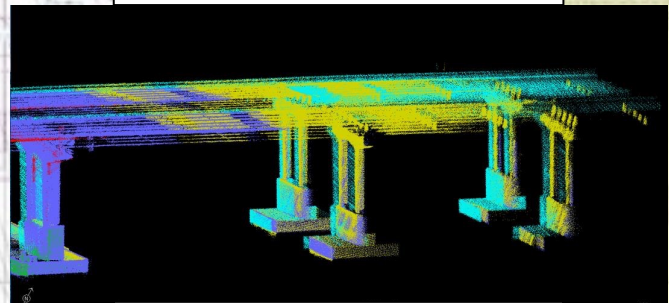
Shorelines, Aids to Navigation (ATON) & Overhead Obstructions

In addition to land surveying and photogrammetry, LIDAR is an efficient way to survey shorelines, ATONs and overhead obstruction

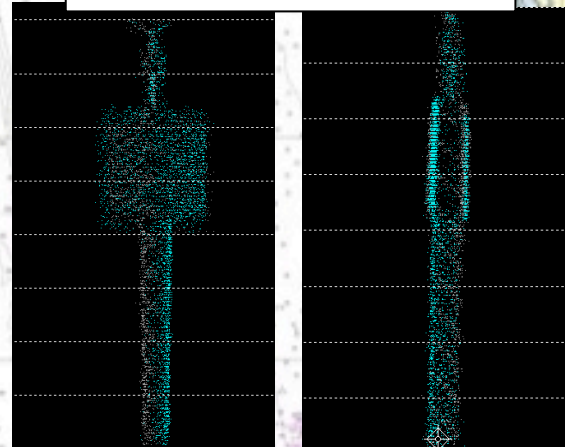


Velodyne LIDAR on USM vessel

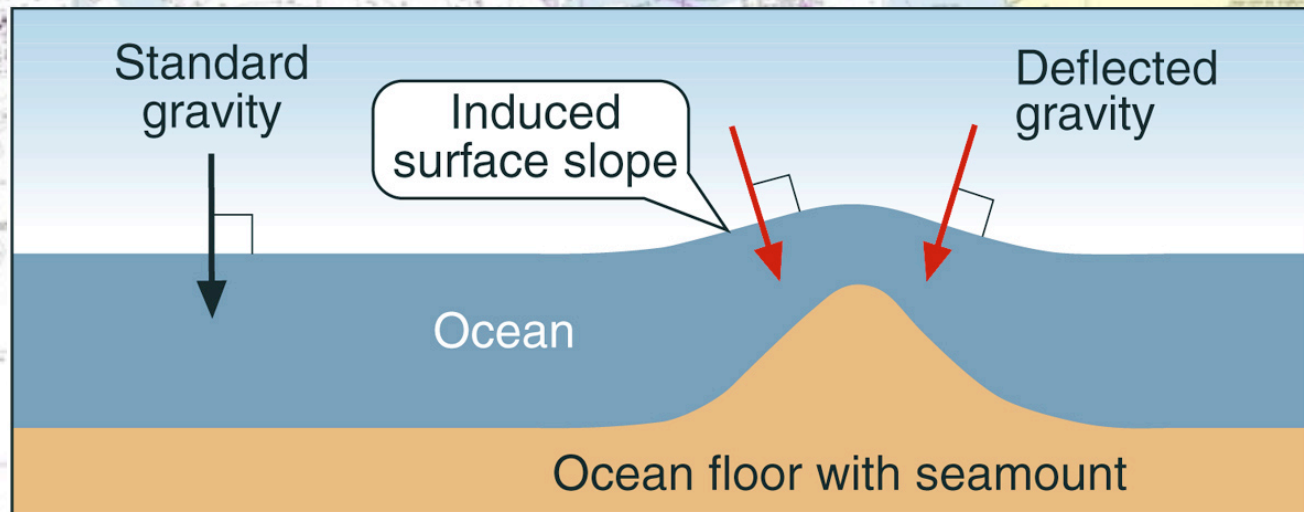
Bridge



ATONS



Satellite Altimetry and Bathymetry



Space radar can sense ocean surface slopes, manifestations of gravity anomalies in the form of deflections of the vertical. These may be correlated with sea floor structure.

Figure from Smith (2003)

Maritime Defense and Security

USS San Francisco Accident

World oceans
altimetry-mapped
– 5 km resolution

Moon radar-
mapped -100m

Mars radar-
mapped – 20m

Venus radar-
mapped – 100m

Geotimes

MARCH 2005

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News Notes

Science and Society

Submarine hits unmapped mountain



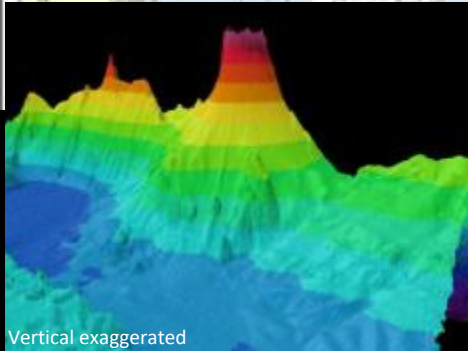
A U.S. Navy submarine cruising 350 miles south of Guam hit an unmapped seamount, leaving one person dead and more than 20 people injured on Jan. 8. The USS San Francisco had been operating under normal procedures without radar, to avoid surveillance, while using U.S. Navy seafloor maps and satellite imagery. Surface photography seemingly had captured the shadow of the seamount, as it almost breaks above sea level, but had placed the underwater mountain several hundred meters away from its actual position. The vast majority of seamounts in the world's oceans remain unexplored. Photo courtesy of U.S. Navy; by Photographer's Mate 2nd Class Mark Allen Leonasio.

[Back to top](#)

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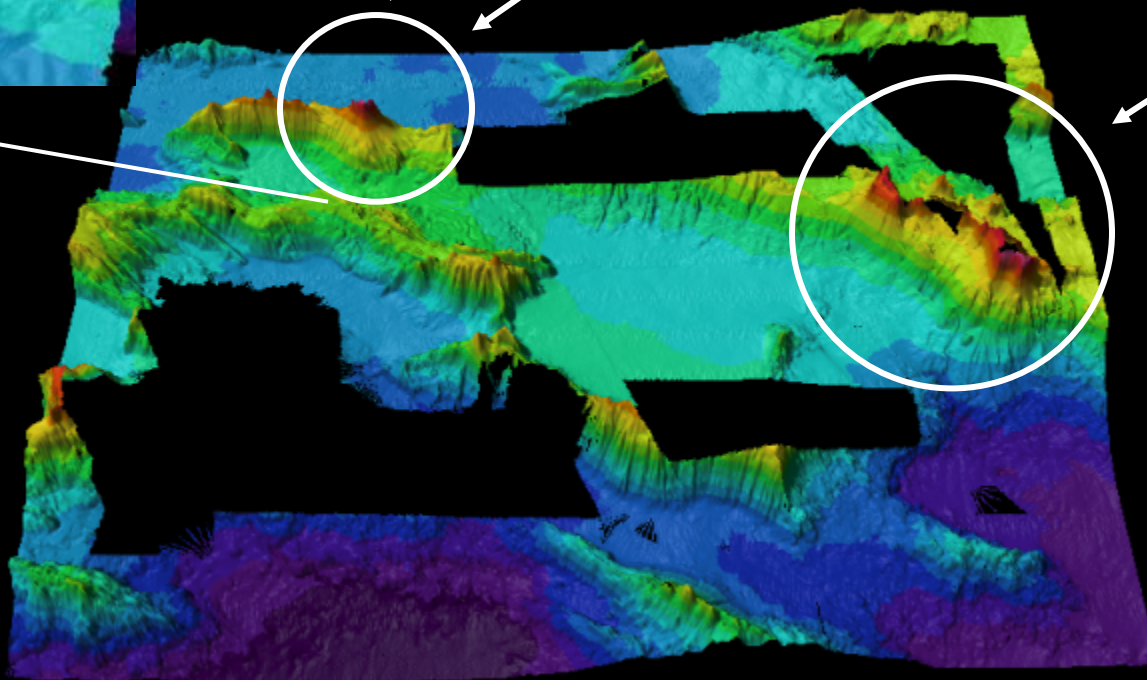
San Francisco Grounding Location Survey

SFO Grounding Survey Polygon



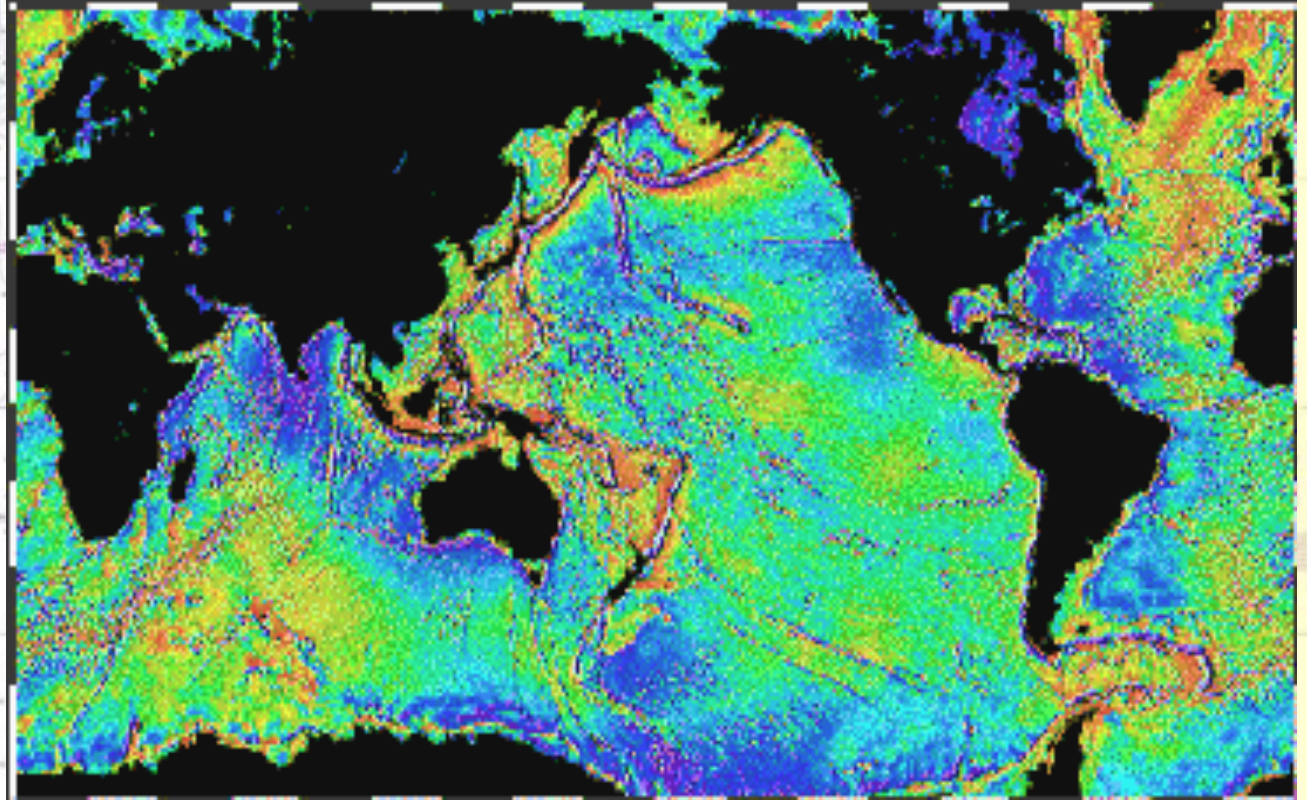
SFO Grounding

New feature



Maritime Defense and Security

Bathymetric
Model from
Satellite
Altimetry



Smith and Sandwell Altimetry Model used to establish potential hazards to Navigation

A detailed nautical chart of the Gulf of Mexico and Caribbean Sea. The chart features a grid of latitude and longitude lines, depth soundings in fathoms, and various navigational symbols. The title 'KEY WEST TO THE MISSISSIPPI RIVER' is visible in the upper right corner. The text 'SOUNDINGS IN FATHOMS' is at the top left. The chart shows the coastline of the United States and Mexico, with numerous islands and reefs marked. The text 'GULF OF MEXICO' is spread across the lower left portion of the chart.

Hydrographic Survey Standards

- The IHO has standards for 5 orders of surveys that are focused on surveys taken to create or update nautical charts
- National governments may set their own standards
- Private clients may set their own standards



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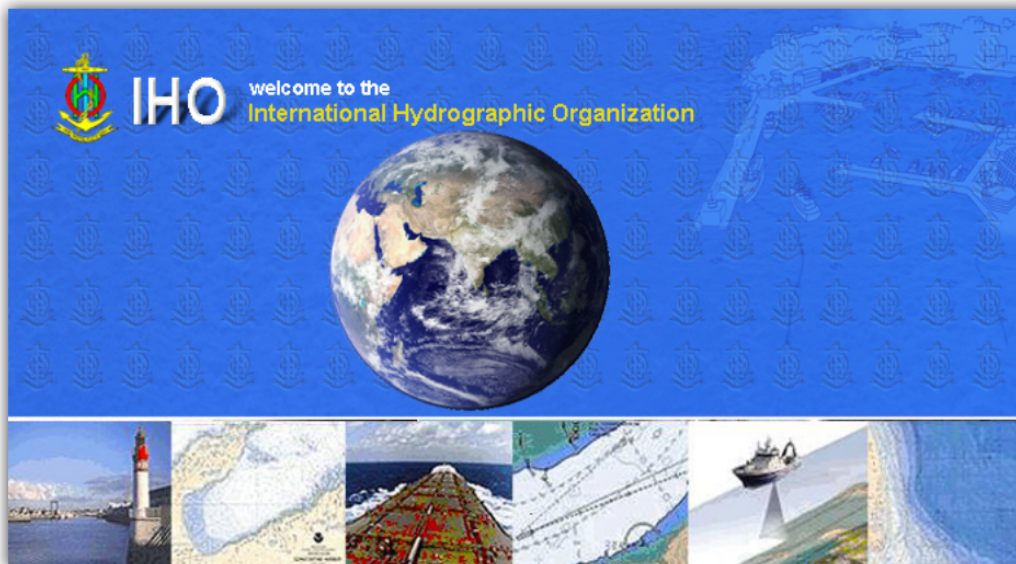
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A principal Aim of the IHO is to ensure that all the world's seas, oceans and navigable waters are surveyed and charted.

The **Mission** of the IHO is to create a global environment in which States provide adequate and timely hydrographic data, products and services and ensure their widest possible use.

The **Vision** of the IHO is to be the authoritative worldwide hydrographic body which actively engages all coastal and interested States to advance maritime safety and efficiency and which supports the protection and sustainable use of the marine environment.

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IHO Water Level Requirements

Reference S-44 IHO Standards for Hydrographic Surveys

S-44 Edition 6.0.0



International Hydrographic Organization
Standards for Hydrographic Surveys

IHO



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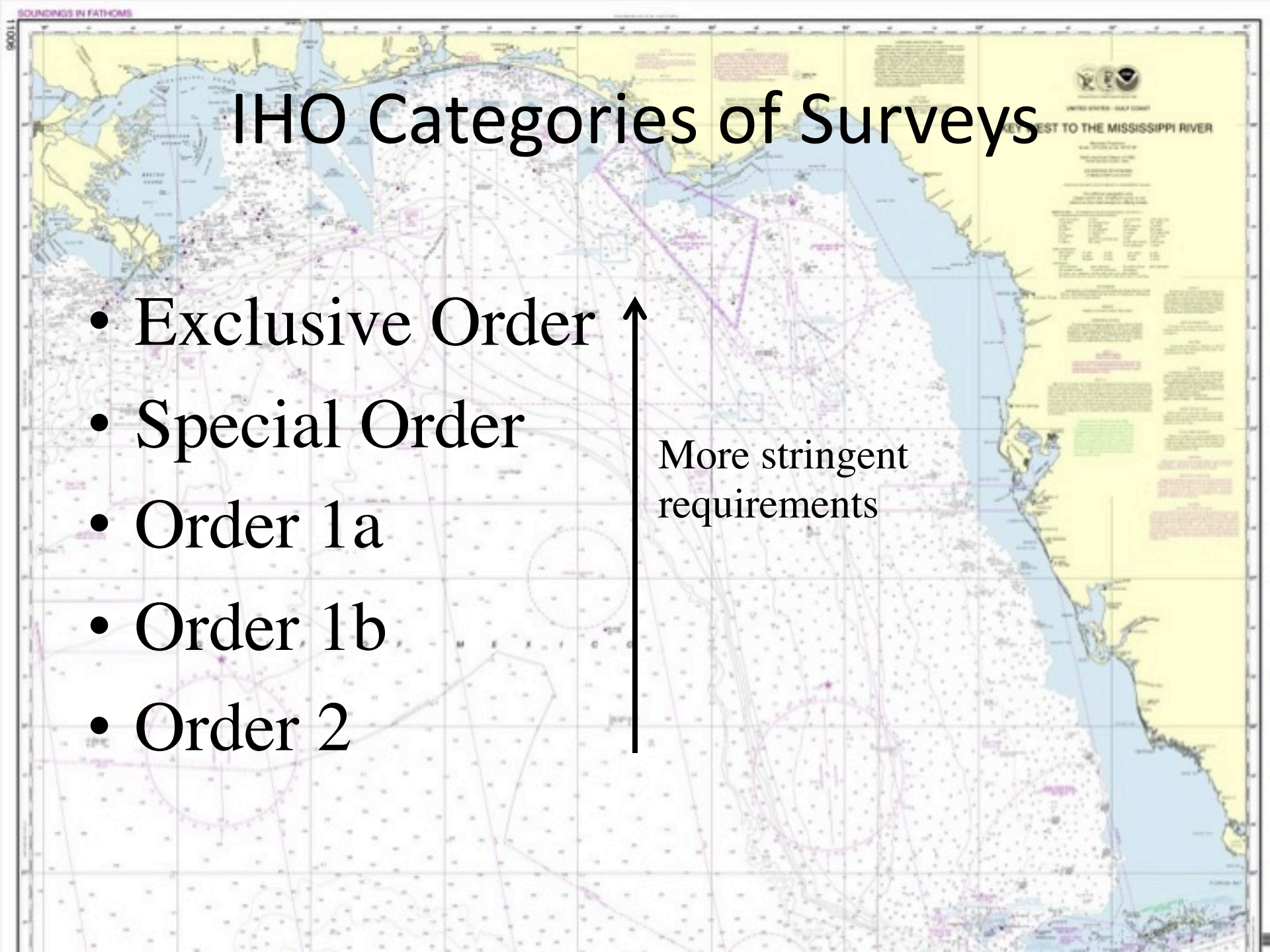
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IHO Categories of Surveys

- Exclusive Order
- Special Order
- Order 1a
- Order 1b
- Order 2

More stringent requirements



7.3 TABLE 1 - Minimum Bathymetry Standards for Safety of Navigation Hydrographic Surveys

To be read in conjunction with the full text set out in this document, m = metres, all [uncertainties](#) at 95% confidence level, * = Matrix Reference.

Reference	Criteria	Order 2	Order 1b	Order 1a	Special Order	Exclusive Order
Chapter 1	Area description (Generally)	Areas where a general description of the sea floor is considered adequate.	Areas where underkeel clearance is not considered to be an issue for the type of surface shipping expected to transit the area.	Areas where underkeel clearance is considered not to be critical but features of concern to surface shipping may exist.	Areas where underkeel clearance is critical	Areas where there is strict minimum underkeel clearance and manoeuvrability criteria
Section 2.6	Depth THU [m] + [% of Depth]	20 m + 10% of depth *Ba5, Bb2	5 m + 5% of depth *Ba8, Bb3	5 m + 5% of depth *Ba8, Bb3	2 m *Ba9	1 m *Ba10
Section 2.6 Section 3.2 Section 3.2.3	Depth TVU (a) [m] and (b)	a = 1.0 m b = 0.023 *Bc7, Bd4	a = 0.5 m b = 0.013 *Bc8, Bd6	a = 0.5 m b = 0.013 *Bc8, Bd6	a = 0.25 m b = 0.0075 *Bc10, Bd8	a = 0.15 m b = 0.0075 *Bc12, Bd8
Section 3.3	Feature Detection [m] or [% of Depth]	Not Specified	Not Specified	Cubic features > 2 m, in depths down to 40 m; 10% of depth beyond 40 m *Be5, Bf3 beyond 40m	Cubic features > 1 m *Be6	Cubic features > 0.5 m *Be9
Section 3.4	Feature Search [%]	Recommended but Not Required	Recommended but Not Required	100% *Bg9	100% *Bg9	200% *Bg12
Section 3.5	Bathymetric Coverage [%]	5% *Bh3	5% *Bh3	≤ 100% *≤ Bh9	100% *Bh9	200% *Bh12

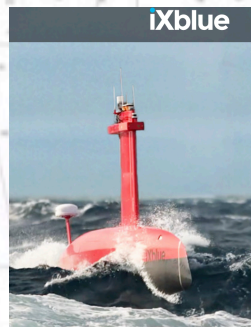
New Directions in Hydrography

- New techniques & technologies for shallow water mapping
 - Drones
 - Digital cameras and structure from motion
 - Compact LIDAR systems
- Citizen science and crowd-sourcing
- Uncrewed vessels

Reigl
BathyCopter



Saildrone



DRIX



C-Worker 5

A nautical chart of the Gulf of Mexico and the western coast of North America, showing soundings in fathoms, depth contours, and various navigational symbols. The chart is titled 'KEY WEST TO THE MISSISSIPPI RIVER' and includes the NOAA logo and 'UNITED STATES NAVAL YACHTS' text.

Summary

- Hydrography provides the geospatial framework for oceanography and coastal sciences
- Hydrographic surveying is moving from being focused on mapping the seafloor for nautical charts to exploiting all of the information in the backscatter from the seafloor and water column for multiple uses (“map once, use many times”)
- Hydrographic practices are evolving along with the technology

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THE NIPPON FOUNDATION-GEBCO **SEABED 2030**

The Nippon Foundation-GEBCO Seabed 2030 Project

<https://seabed2030.org/>

100% of the ocean floor mapped by 2030

- Collaborative project Nippon Foundation of Japan and General Bathymetric Chart of the Oceans (GEBCO)
- UN Ocean Decade Action

A nautical chart of the Gulf of Mexico and the western coast of the United States, showing soundings in fathoms, depth contours, and various navigational symbols. The chart is titled 'KEY WEST TO THE MISSISSIPPI RIVER' and includes a scale of 1:50,000. The word 'Resources' is overlaid in large black text in the upper center of the chart.

Resources

- IHO www.iho.int
 - Publications https://www.iho.int/iho_pubs/IHO_Download.htm
 - C-47 TRAINING COURSES IN HYDROGRAPHY AND NAUTICAL CARTOGRAPHY
<https://iho.int/uploads/user/pubs/cb/c-33/C47E-SEPT09-UPDATED-APRIL11.pdf>
- NOAA Office of Coast Survey
 - <https://www.nauticalcharts.noaa.gov/index.html>
 - <https://nauticalcharts.noaa.gov/publications/standards-and-requirements.html>
- University Corporation for Atmospheric Research (UCAR) COMET Program
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