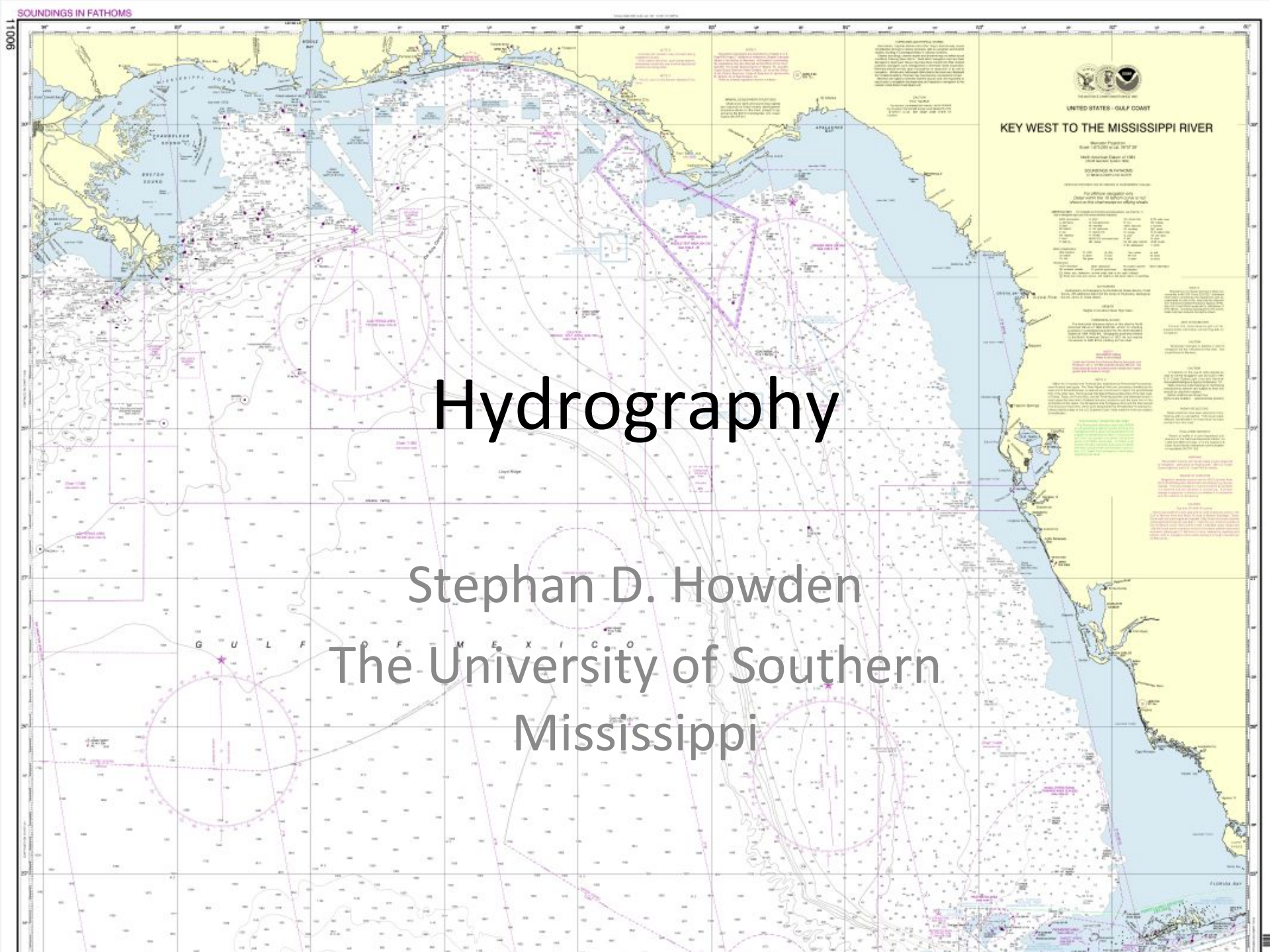


Hydrography

Stephan D. Howden

The University of Southern Mississippi



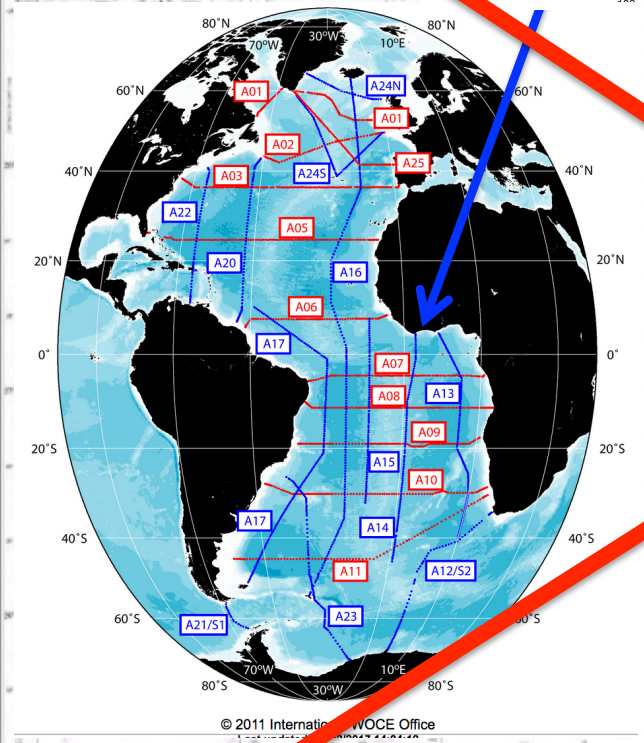




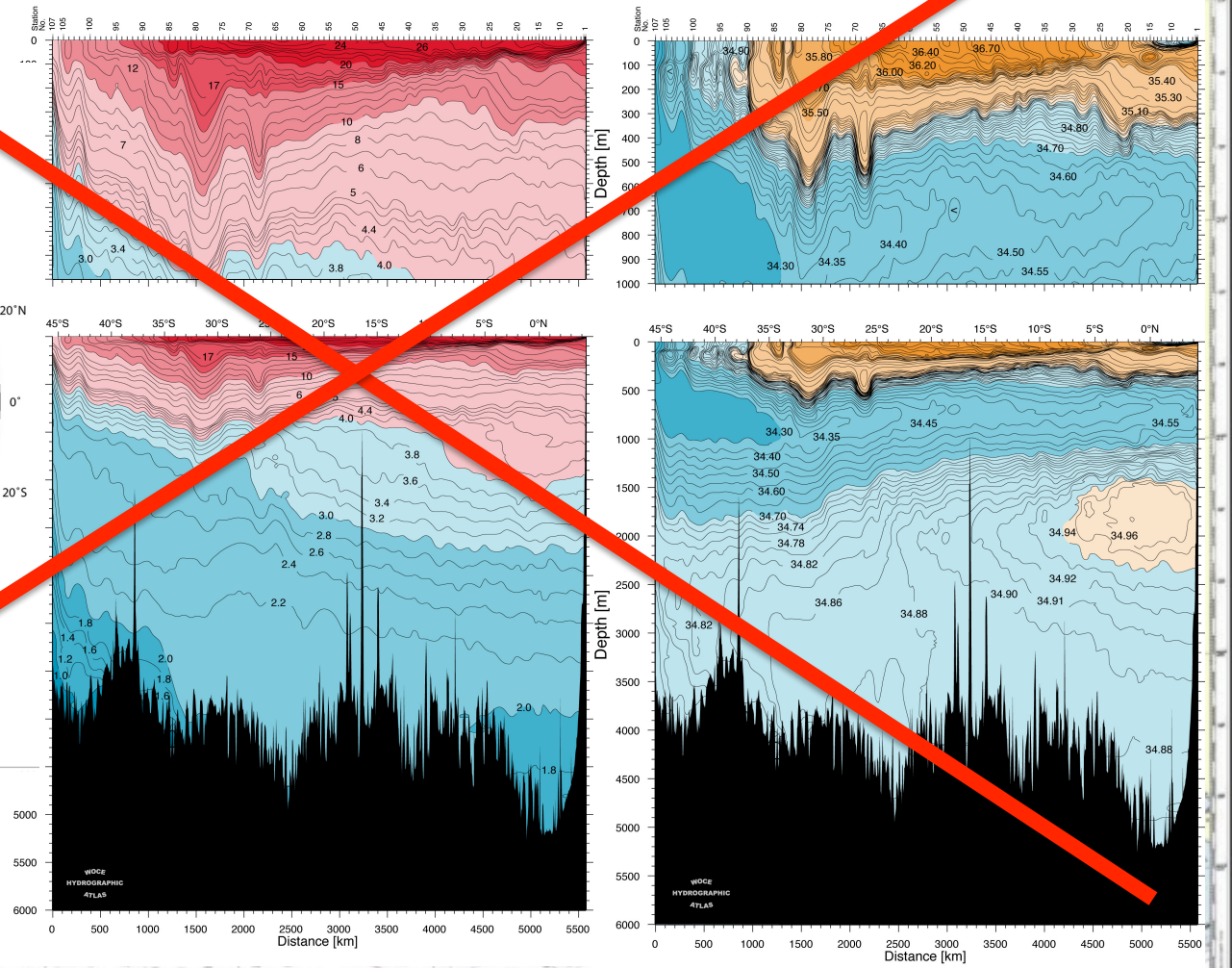


What is Hydrography?

WOCE Section A14



Potential Temperature [°C] for A14 5°W



CTD Salinity for A14 5°W

INTERNATIONAL HYDROGRAPHIC ORGANIZATION

www.iho.int/

What is Hydrography?

- **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. -IHO

International Hydrographic Organization*

- 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

International Hydrographic Organization
Organisation Hydrographique Internationale

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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

IHO Categories of Surveys

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

More stringent requirements

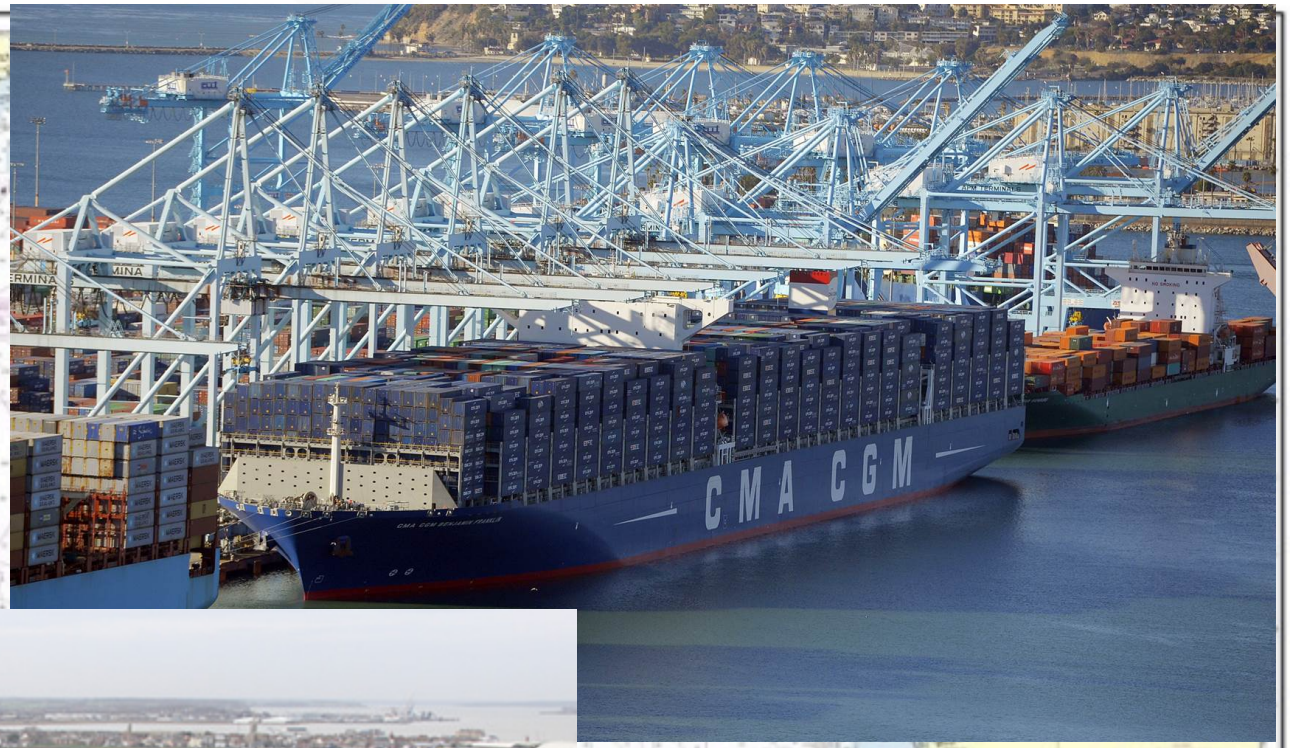
TABLE 1
Minimum Standards for Hydrographic Surveys
(To be read in conjunction with the full text set out in this document.)

Reference	Order	Special	1a	1b	2
Chapter 1	**Description of areas.**	Areas where under-keel clearance is critical	Areas shallower than 100 metres where under-keel clearance is less critical but *features* of concern to surface shipping may exist.	Areas shallower than 100 metres where under-keel clearance is not considered to be an issue for the type of surface shipping expected to transit the area.	Areas generally deeper than 100 metres where a general description of the sea floor is considered adequate.
Chapter 2	**Maximum allowable THU 95%** *Confidence level*	2 metres	5 metres + 5% of depth	5 metres + 5% of depth	20 metres + 10% of depth
Para 3.2 and note 1	**Maximum allowable TVU 95%** *Confidence level*	a = 0.25 metre b = 0.0075	a = 0.5 metre b = 0.013	a = 0.5 metre b = 0.013	a = 1.0 metre b = 0.023
Glossary and note 2	*Full Sea floor Search*	Required	Required	Not required	Not required
Para 2.1 Para 3.4 Para 3.5 and note 3	*Feature Detection*	Cubic *features* > 1 metre	Cubic *features* > 2 metres, in depths up to 40 metres; 10% of depth beyond 40 metres	Not Applicable	Not Applicable
Para 3.6 and note 4	**Recommended maximum Line Spacing**	Not defined as *full sea floor search* is required	Not defined as *full sea floor search* is required	3 x average depth or 25 metres, whichever is greater For bathymetric lidar a spot spacing of 5 x 5 metres	4 x average depth
Chapter 2 and note 5	**Positioning of fixed aids to navigation and topography significant to navigation. (95%** *Confidence level*)	2 metres	2 metres	2 metres	5 metres
Chapter 2 and note 5	**Positioning of the Coastline and topography less significant to navigation (95%** *Confidence level*)	10 metres	20 metres	20 metres	20 metres
Chapter 2 and note 5	**Mean position of floating aids to navigation (95%** *Confidence level*)	10 metres	10 metres	10 metres	20 metres

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

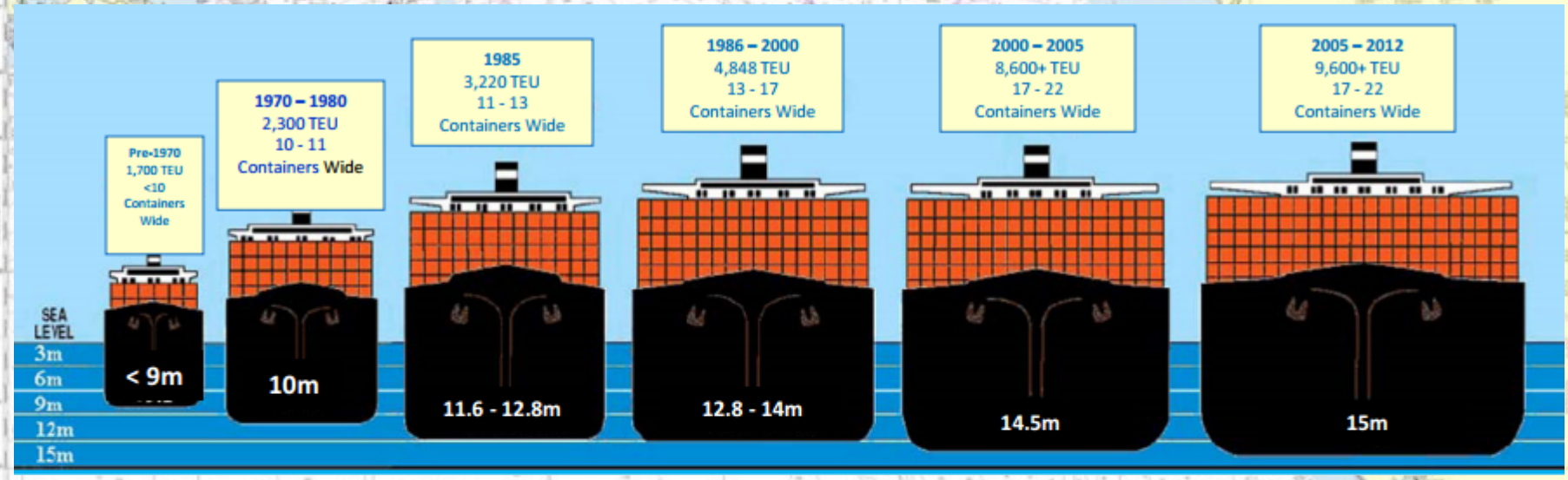
Cargo and container ships rely on accurate charts.



These ships move 95% of all international goods.

Increasing Drafts of Large Container Ships

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

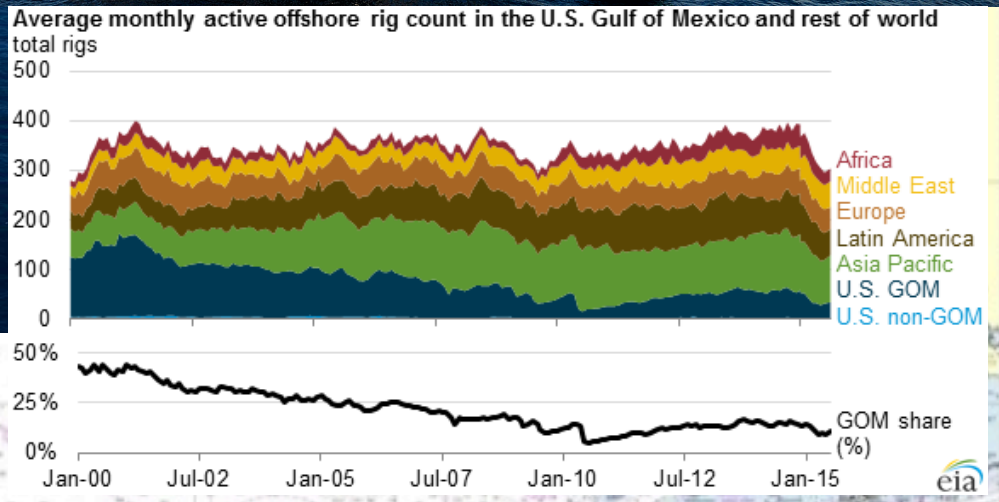


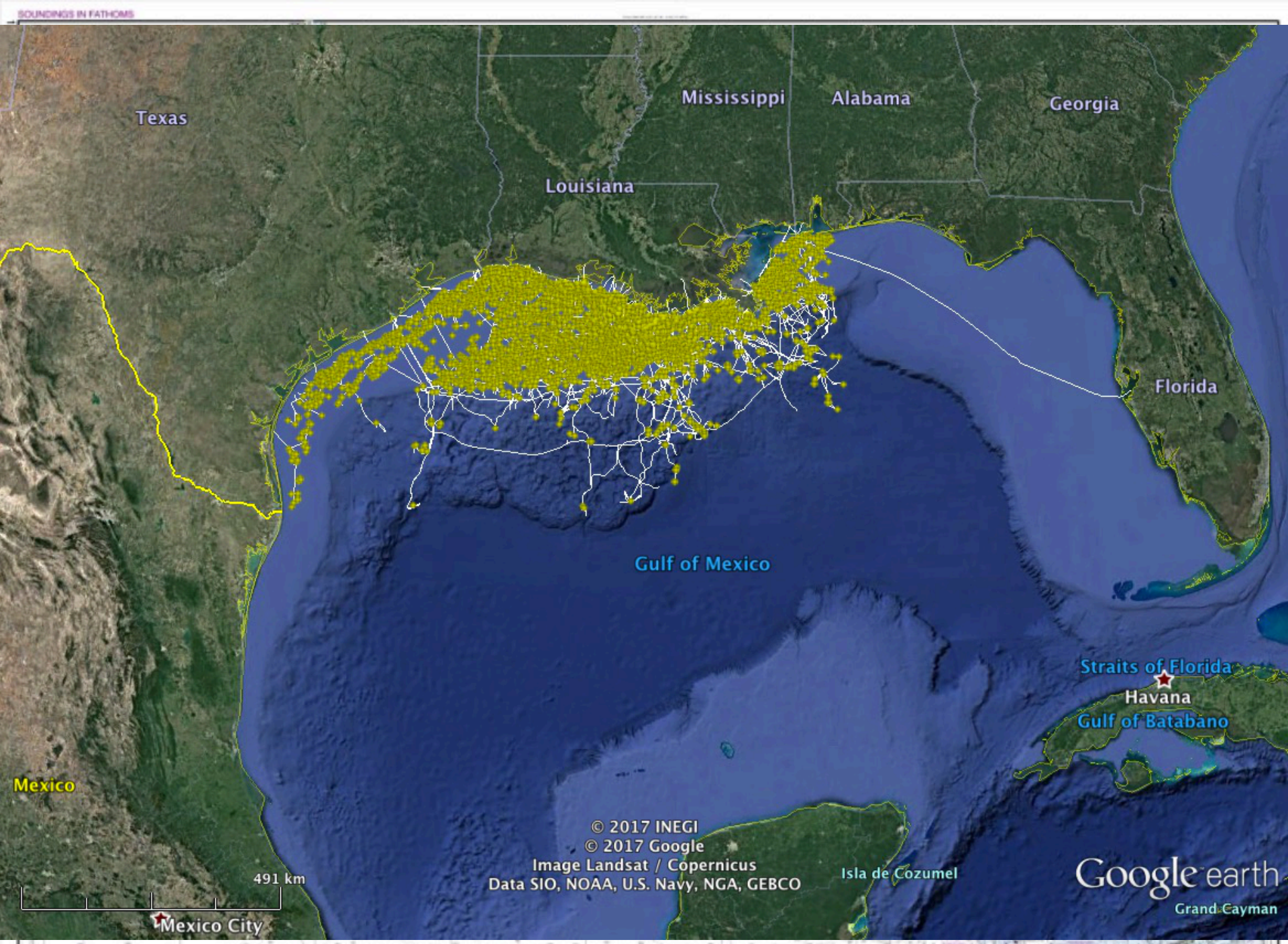
Uncharted waters: Mega cruise ships sail the Arctic

Crystal Serenity Cruise Ship Completes Historic Northwest Passage Arctic Journey – Sep 2016

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

Resource Exploitation Oil/Gas

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Georgia
Louisiana
Florida
Gulf of Mexico
Straits of Florida
Havana
Gulf of Batabano
Mexico
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Grand Cayman
491 km
Mexico City

Resource Exploitation
Offshore Wind Farms

Maritime Boundaries Delimitation

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.

By Thomas Omestad Oct. 9, 2008 Leave a Comment SHARE

Basics of What is in a Chart

- A mathematical model of the earth as an ellipsoid of revolution (dimensions and orientation), also known as a horizontal datum onto which we prescribe latitude and longitude
- Positions of the coastline in the horizontal datum
- Positions of Aids to Navigation and Dangers to Navigation in the horizontal datum
- Heights of overhead obstructions with respect to a high tidal water level, and their positions with respect to the horizontal datum
- Depths of water with respect to a low water level ("chart datum"), and their positions with respect to the horizontal datum
- Cartographic rules for depicting the data on the horizontal datum in 2-D (either paper or electronically)

Horizontal/3-D Datums: Geodetic Datums

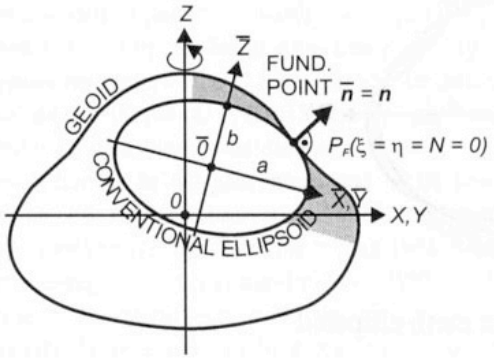


Fig. 7.4. Locally fitting "conventional" ellipsoid

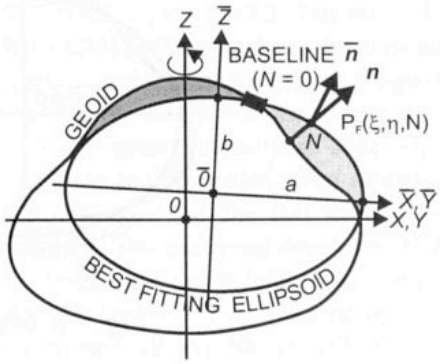


Fig. 7.5. Regionally best fitting ellipsoid

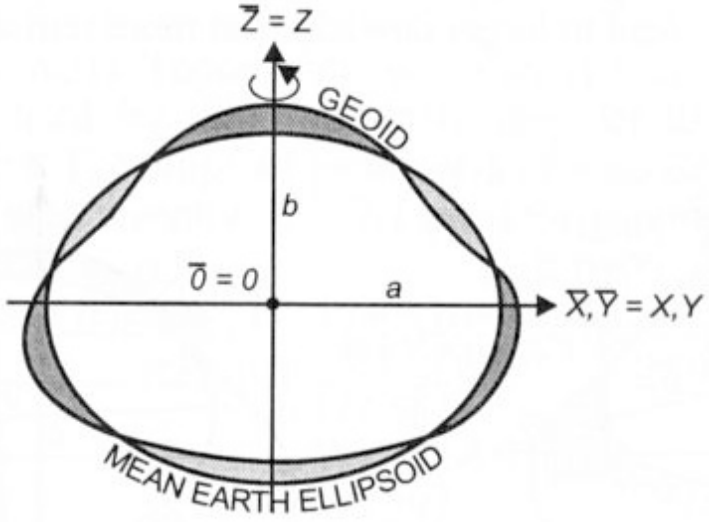


Fig. 7.6. Mean earth ellipsoid

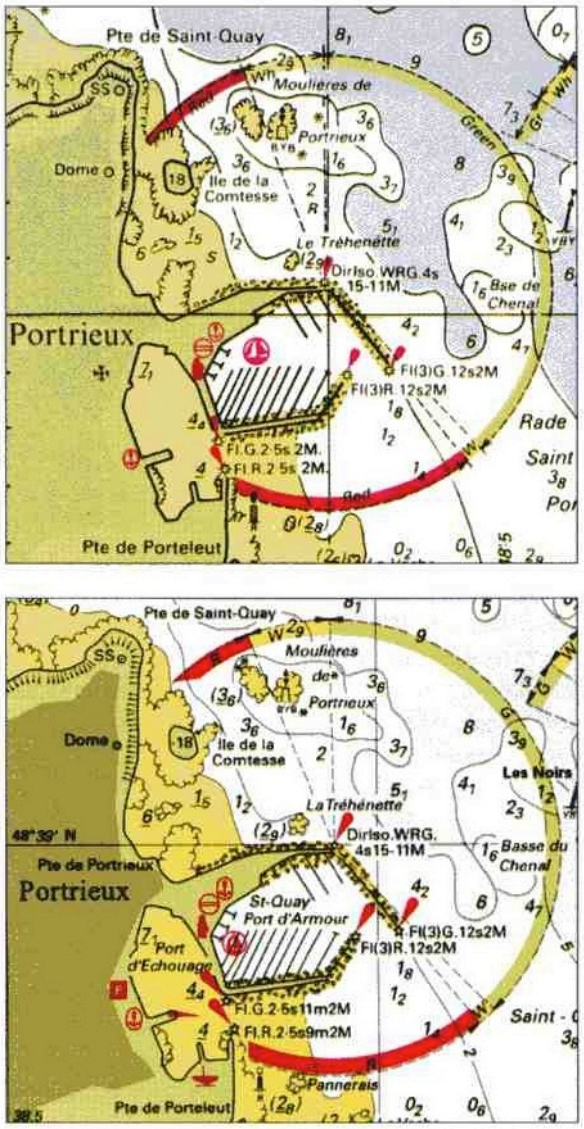
Source: Torge (2011).

Geodetic Datum:

- Size (e.g., semi-major axis and semi-minor axis lengths)
- Orientation to the Earth
- Modern way to navigate in this system is the GNSS

Different Geodetic Datums, Different Latitude and Longitude

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



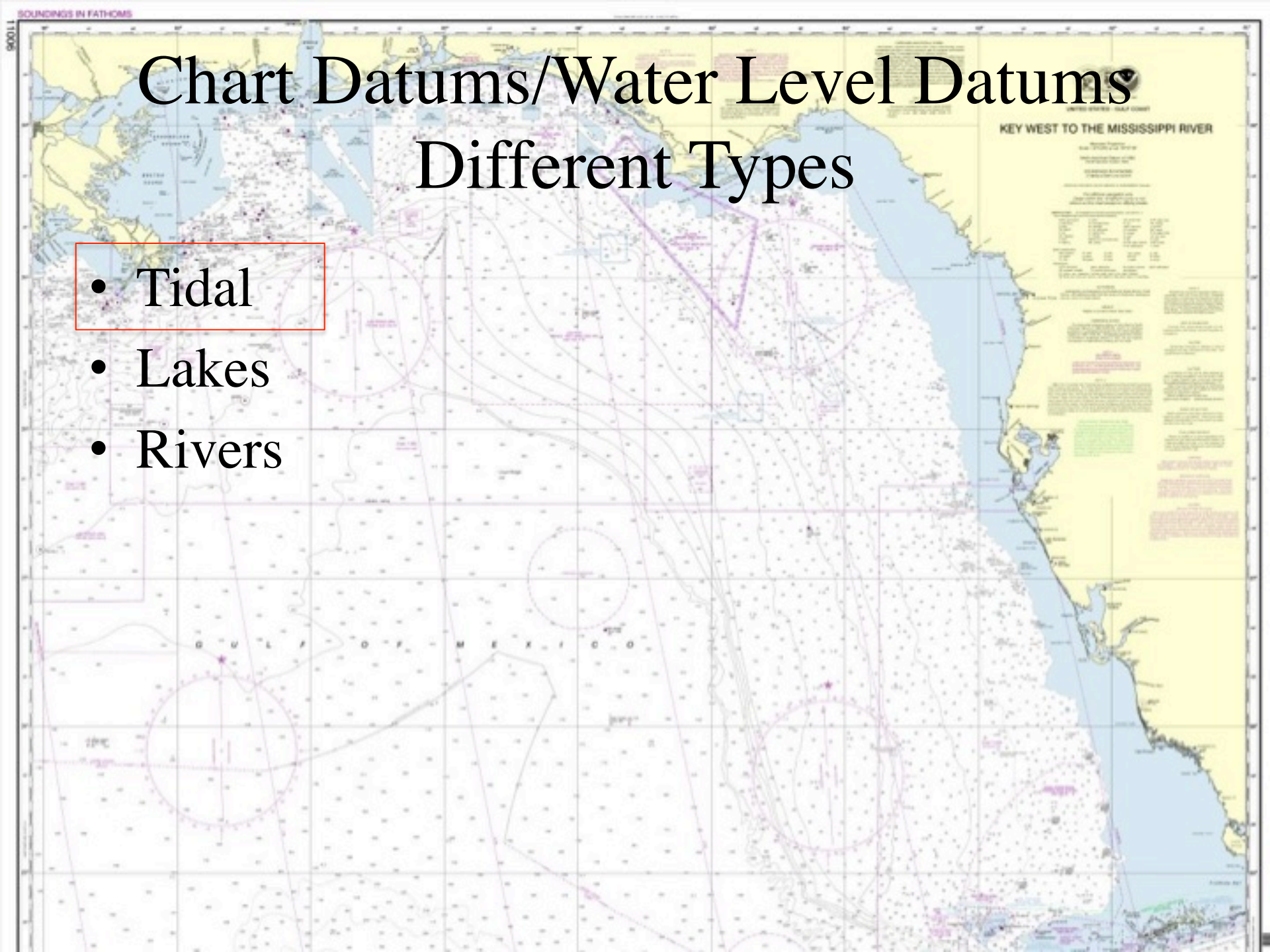
Source: Nigel Calder, How to Read a Nautical Chart, McGraw-Hill, 2003, 237pp.

Coastline, Aids to Navigation (ATONs) and Dangers to Navigation (DTONs)

- Coastline
  - Photogrammetry
  - Satellite imagery
  - LIDAR (Laser
  - Land Surveying
- ATONs
  - GNSS (GPS)
- DTONs
  - Acoustic mapping and techniques and precise positioning of vessel (coordinates relative to horizontal datum and chart datum)
    - Single beam echo sounder
    - Mutibeam echo sounder
    - Sidescan sonar

Chart Datums/Water Level Datums
Different Types

- Tidal
- Lakes
- Rivers



Tidal Datums

At each location there are many different tidal datums. Some examples are:

- Mean Sea Level: arithmetic mean of hourly heights observed over the NTDE.
- Mean High Water: average of all high water heights observed over the National Tidal Datum Epoch (NTDE).
- Mean Low Water: average of all low water heights observed over the NTDE.
- Mean Lower Low Water: average of the lower low water height of each tidal day observed over the NTDE.
- Lowest Astronomic Tide: Lowest tide level from harmonic analysis

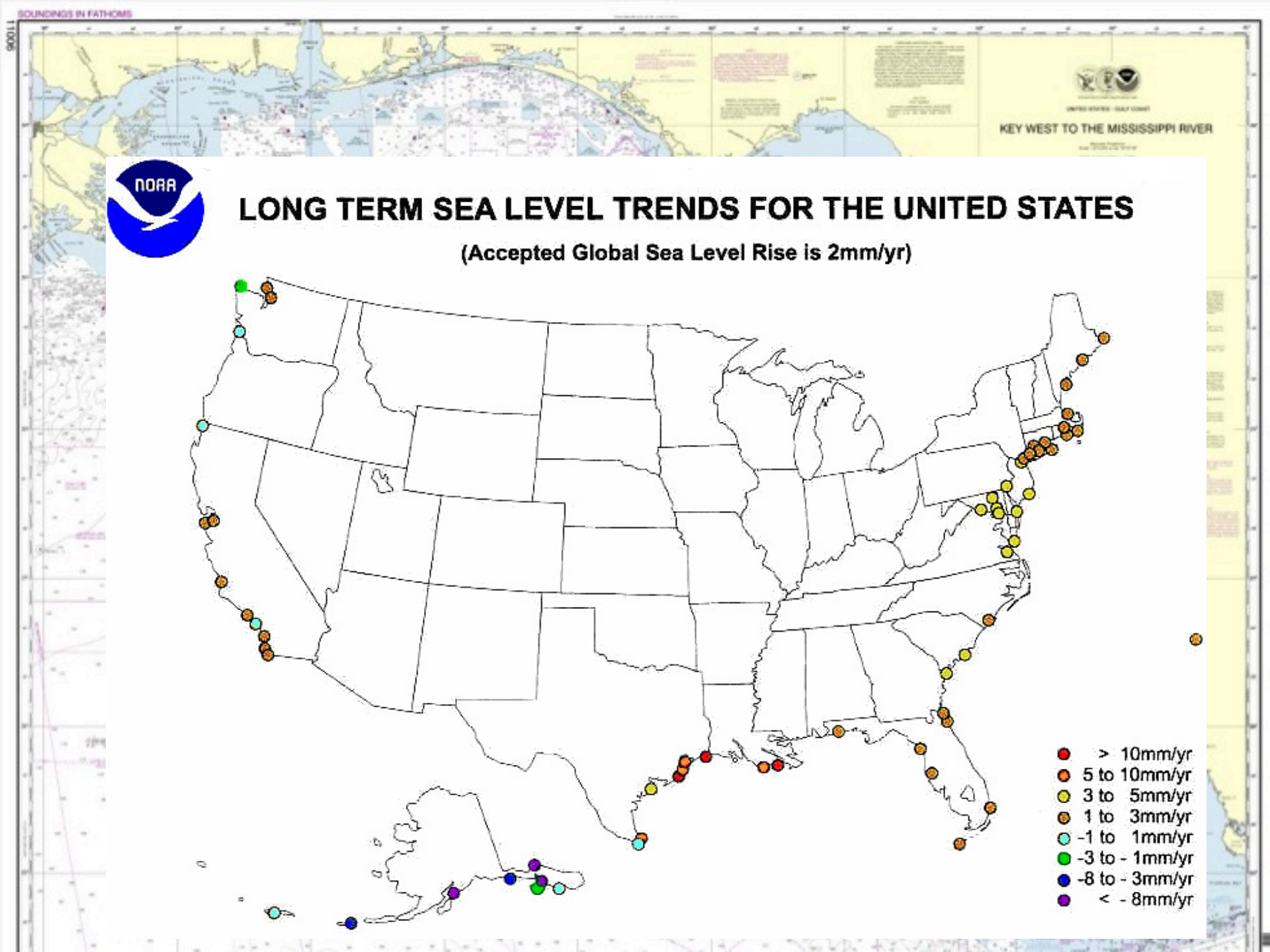
Tidal Datums

- Tidal forcing is well understood and occurs due to the orbital characteristics of the sun, earth and moon, and the diurnal spin of the earth.
- The longest period of practical concern for hydrography is the lunar nodal period of 18.6 years.
- All of the tidal forcing up to this period can be written as a linear combination of 5 periods, e.g.:

1. A mean solar day (MSD)
2. Lunar month, 27.3216 MSD
3. Mean solar year, 365.2422 MSD
4. Lunar perigee period, 3231.4818 MSD (8.85 year)
5. Lunar nodal period, 6798.3661 MSD (18.61 yr)

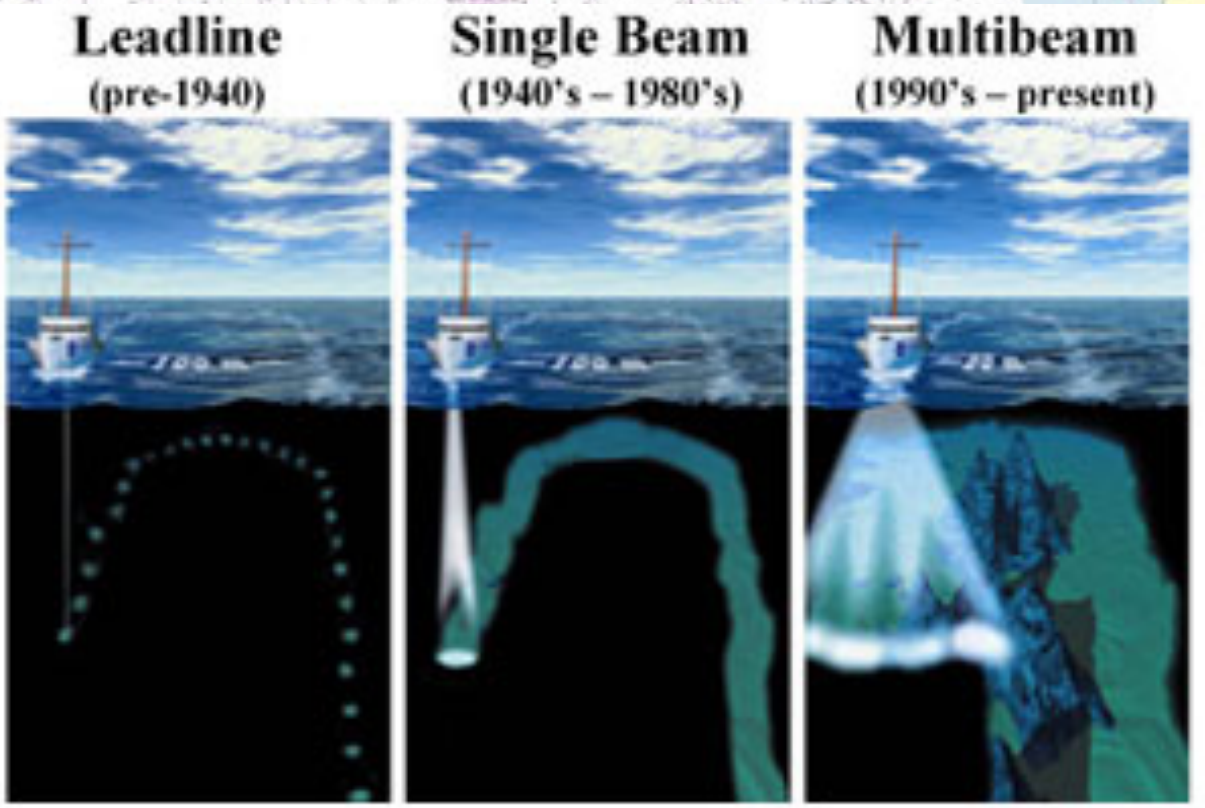
Tidal Datums Require Tide Gauges

- In the US and some other countries there is a national network 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. A technique known as a datum transfer, from a primary gauge is used to obtain equivalent long term datums at the secondary gauge
- In some cases known tidal harmonic constituents and/ or modeling are used to obtain chart datum.


KEY WEST TO THE MISSISSIPPI RIVER
NOAA
LONG TERM SEA LEVEL TRENDS FOR THE UNITED STATES
(Accepted Global Sea Level Rise is 2mm/yr)
> 10mm/yr
5 to 10mm/yr
3 to 5mm/yr
1 to 3mm/yr
-1 to 1mm/yr
-3 to - 1mm/yr
-8 to - 3mm/yr
< - 8mm/yr

Secondary Gauge Installation

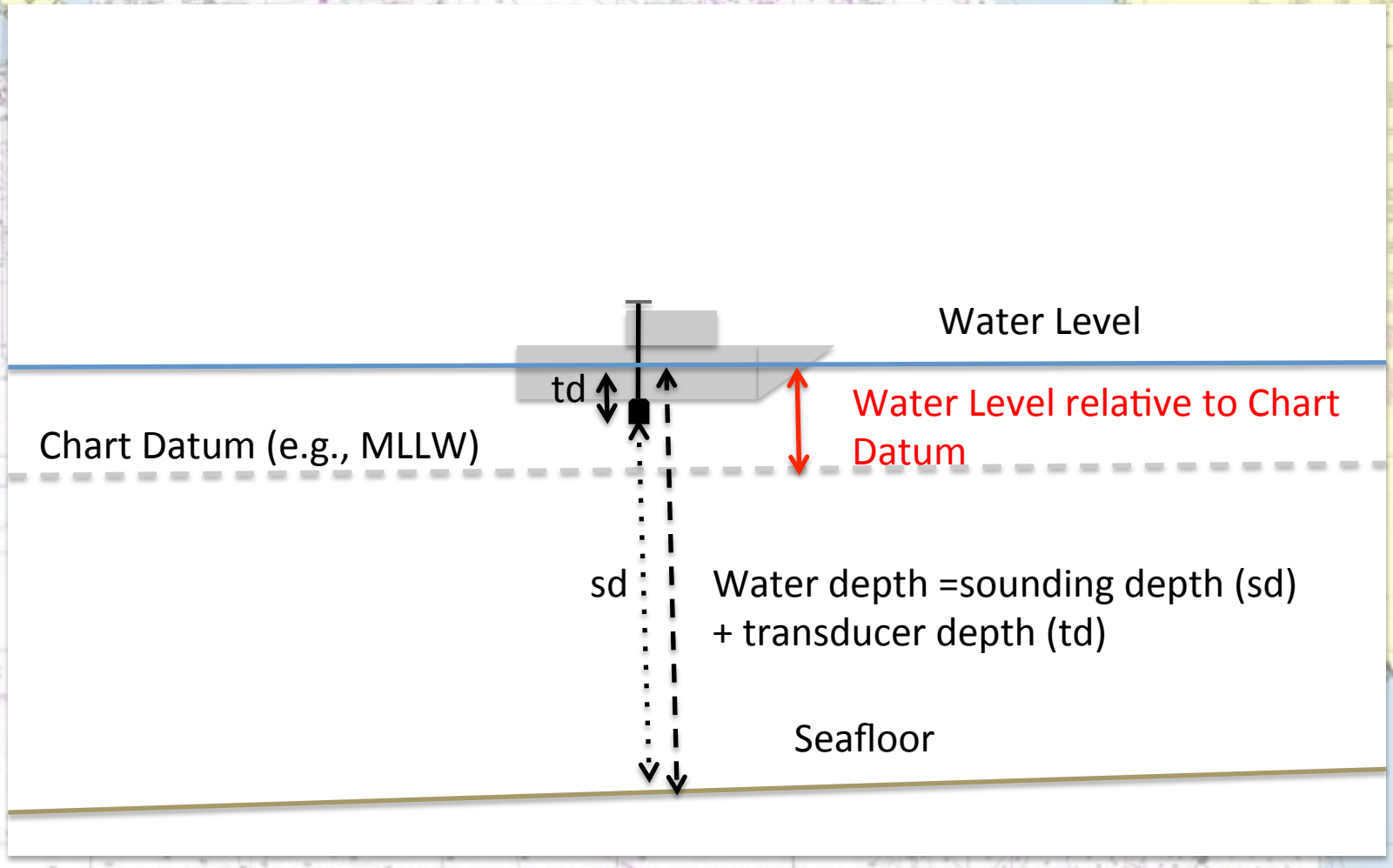
Mapping the Seafloor
From Leadline to Multibeam



https://www.nauticalcharts.noaa.gov/hsd/images/SW_History_lead2mb.jpg

Multibeam Surveying

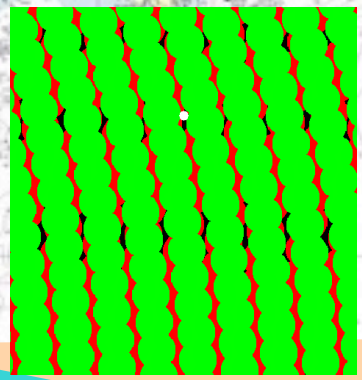
Mapping of Seafloor & Sounding Reduction



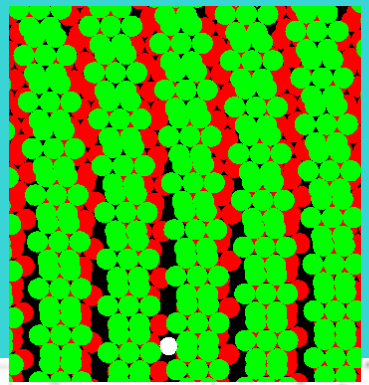
Coastal Zone Mapping and Imaging Lidar

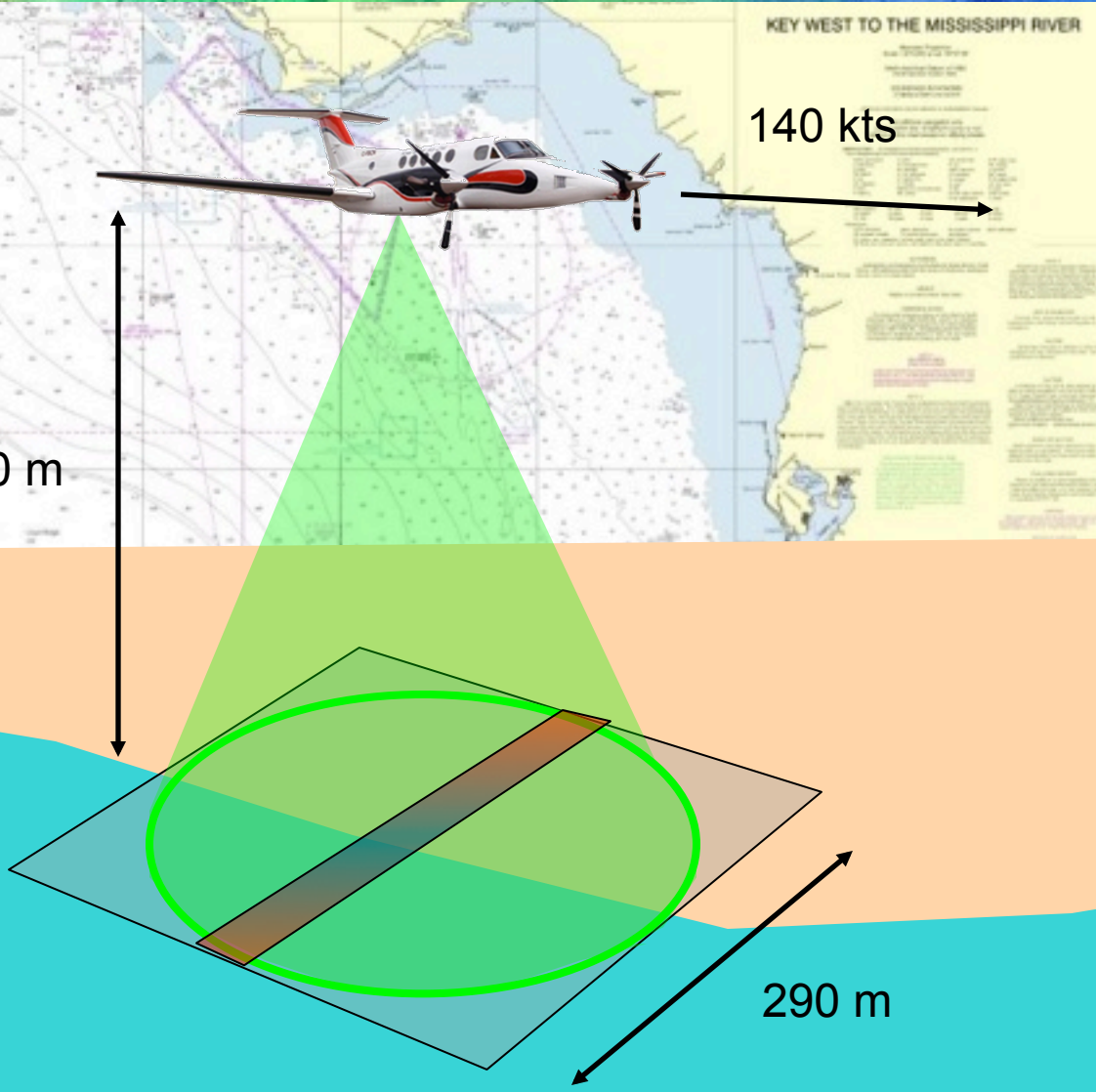
Operational Scenario

Bathymetry
Diameter of laser spot = 2.5 meters
Diameter of largest void = 0.54 meters



Topography
Diameter of laser segment spot = 0.83 meters
Diameter of largest segment void = 0.7 meters

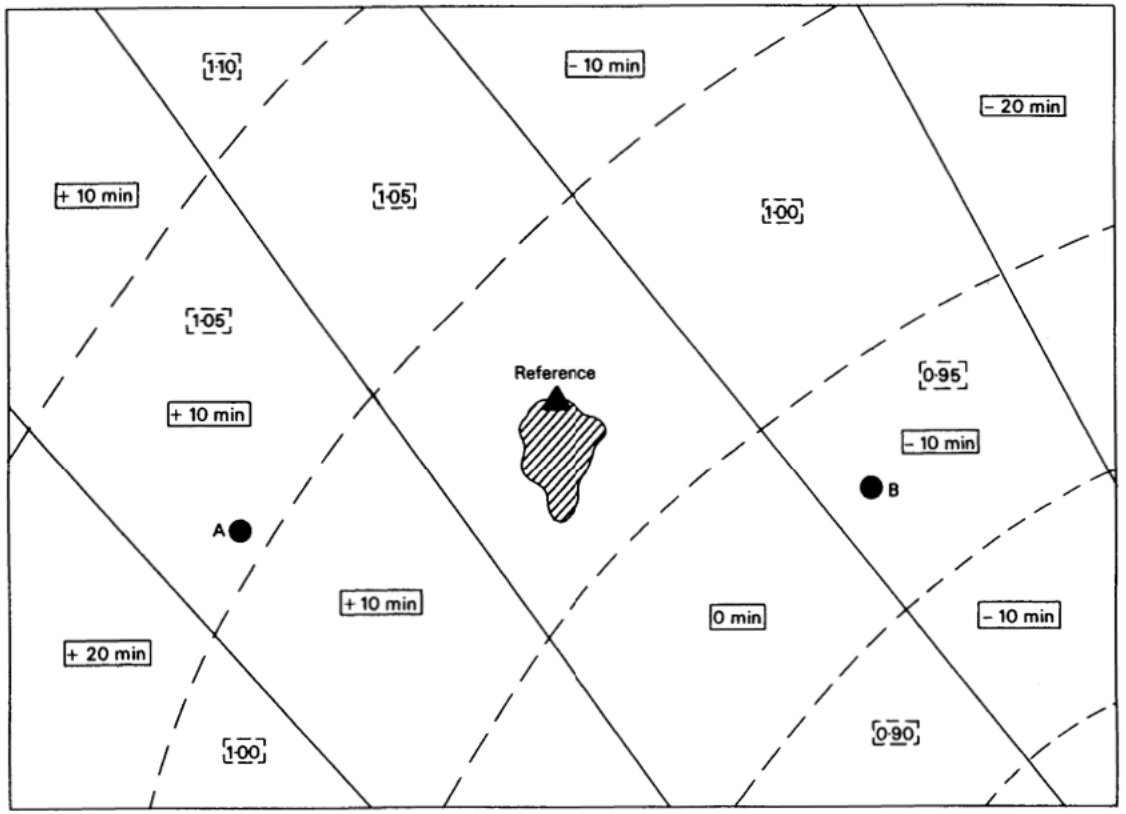




Mapping of Seafloor

When Vessel is Not Right Next to Tide Gauge

Co-Range, Co-Phase Chart



Source: Canadian Tidal Manual

Other Complicating Factors

- Vessel Heave
  - mitigate with low pass filter
- Vessel Pitch and Roll
  - Measure and remove if necessary
- Vessel Squat
  - Measure and remove if necessary
- Vessel Dynamic Draft
  - Measure and remove if necessary
- Sound speed variations and refraction
  - Measure sound speed profiles periodically

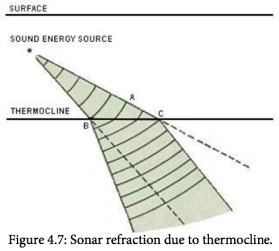
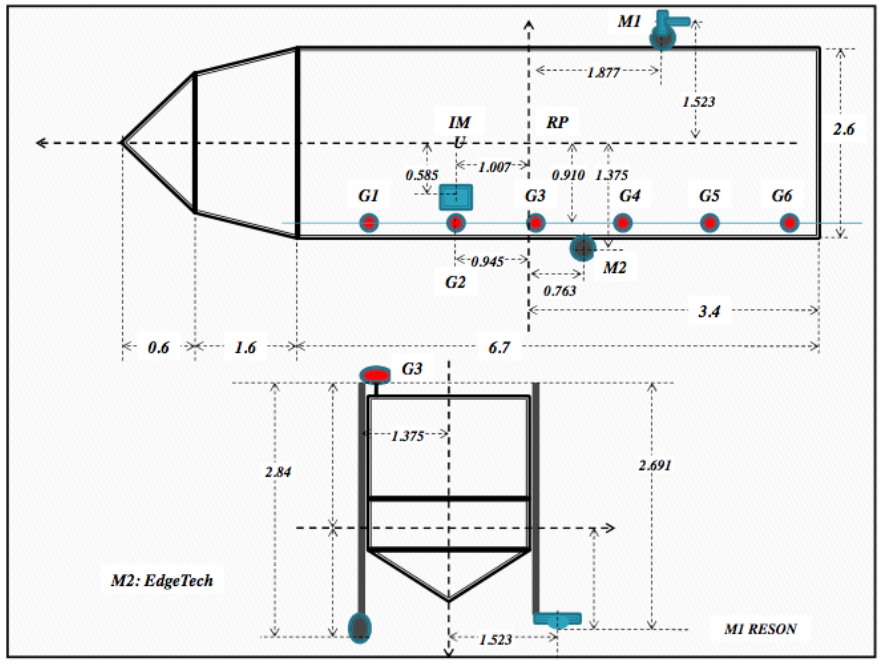
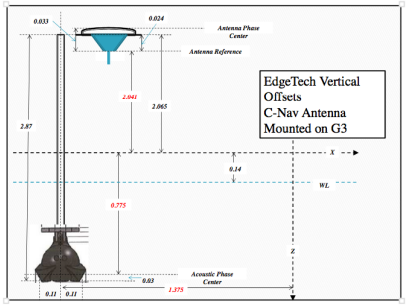


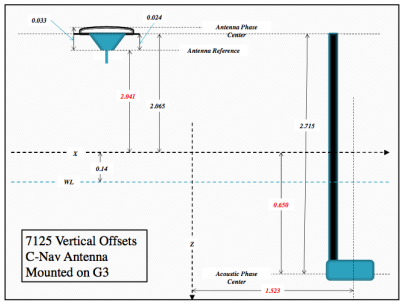
Figure 4.7: Sonar refraction due to thermocline.

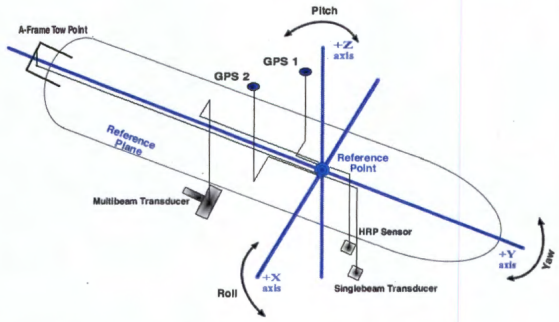
Vessel Configuration Survey

Determine a Vessel Frame of Reference for Instruments (GNSS Antennae, Sonar, etc, to Geolocate Soundings





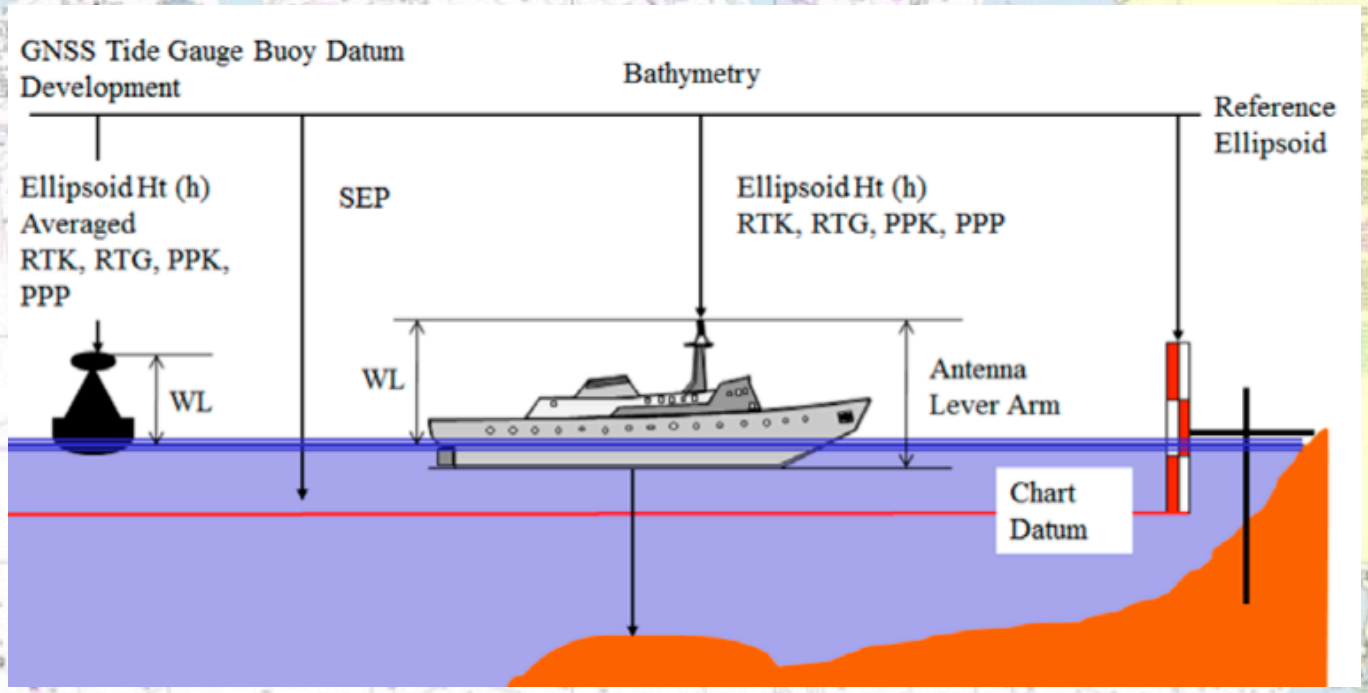




Vessel Configuration Survey

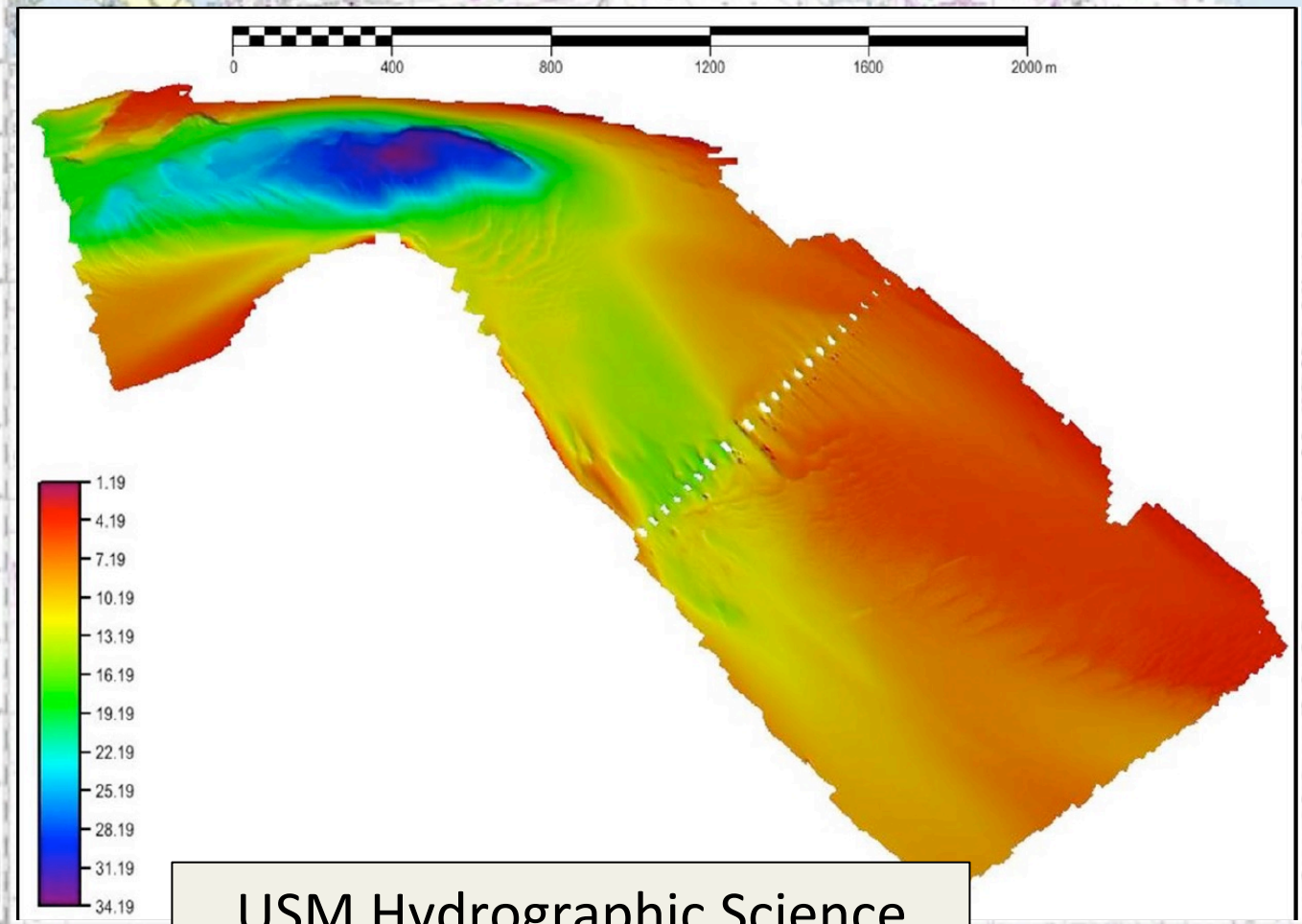
Ellipsoidally Referenced Survey

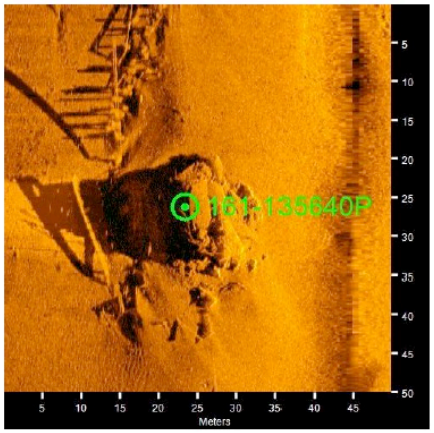
Decoupling Tides from Hydrographic Surveying

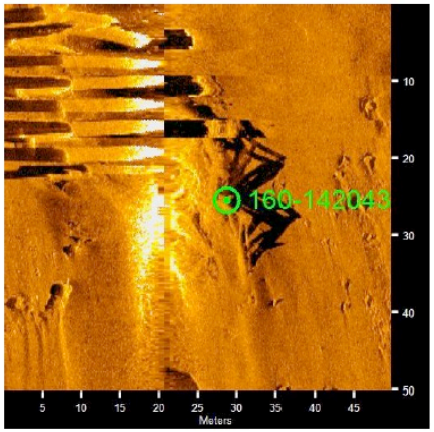


- Water depths are measured to the reference ellipsoid
- The separation between the ellipsoid and chart datum ("separation model") is determined by others (e.g., NOAA in the United States)
- The separation model is used to convert, or reduce, the water depths to chart datum.

Product Examples
Bathymetric Surface & Targets

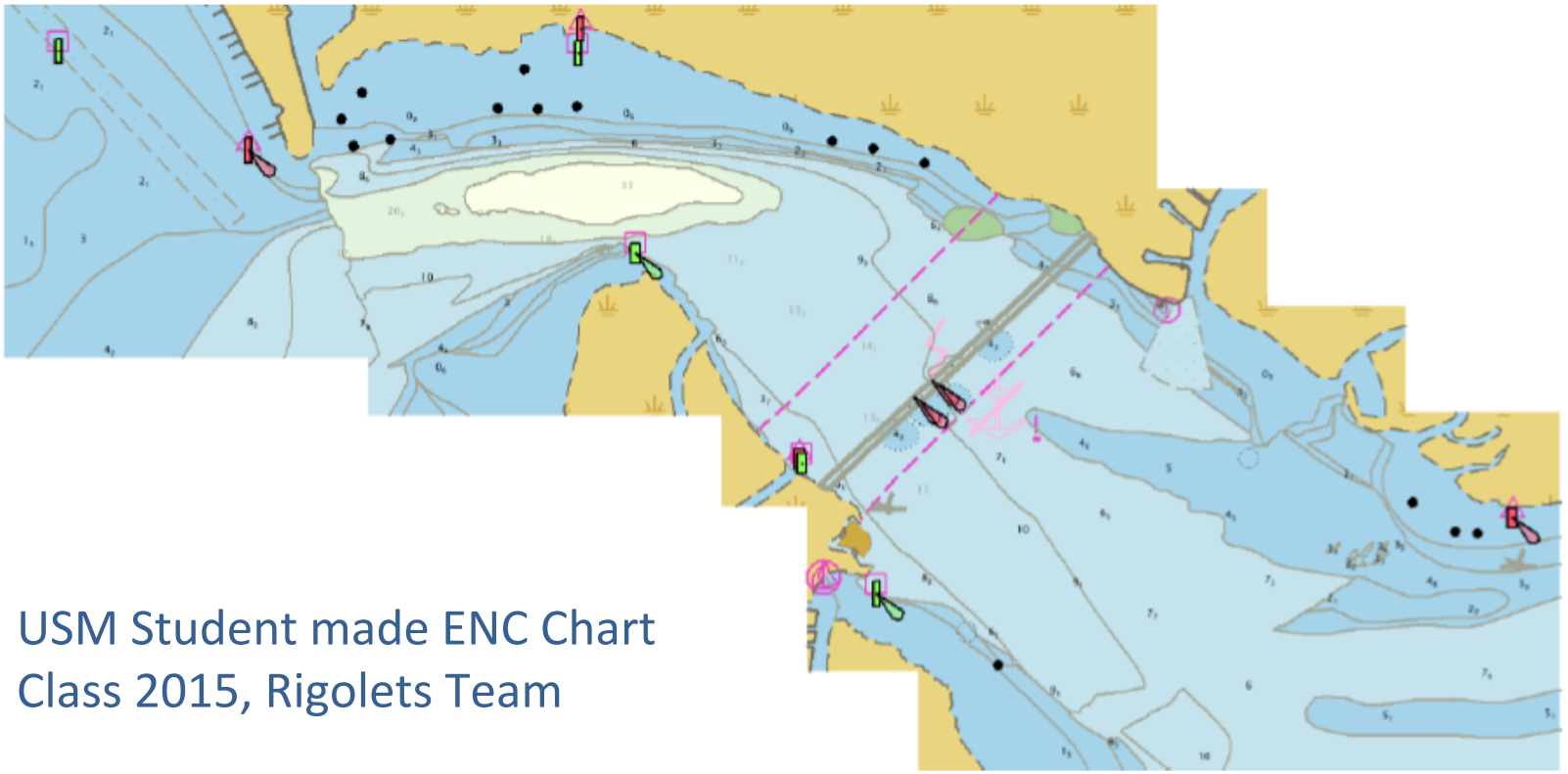






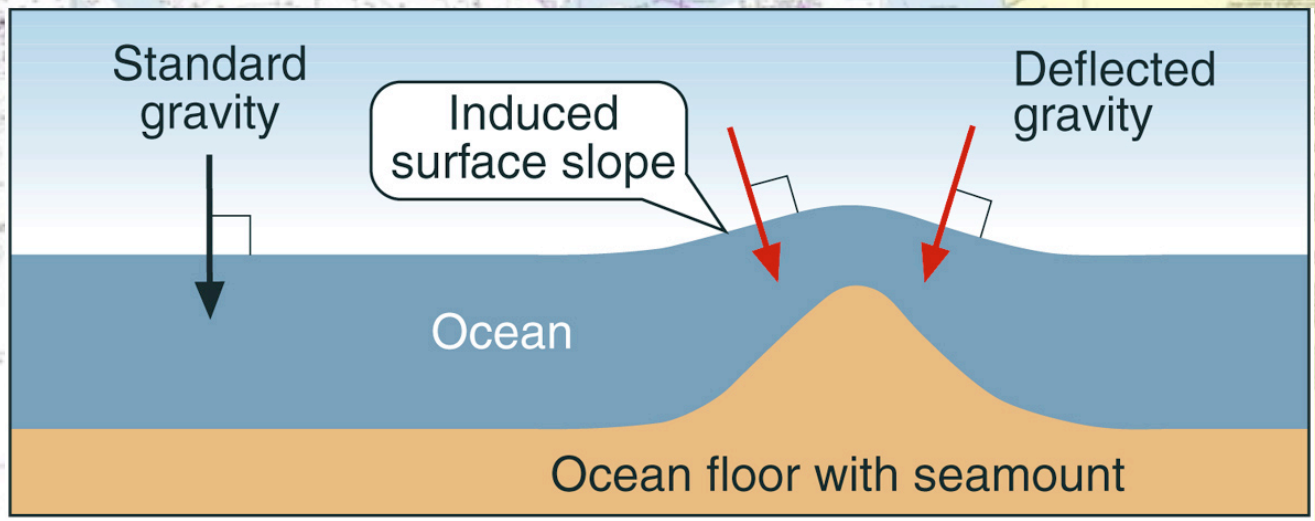
USM Hydrographic Science
Class 2015, Rigolets Team

15USM01: Western Rigolets ENC



USM Student made ENC Chart
Class 2015, Rigolets Team

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

World oceans altimetry-mapped – 5 km resolution

Moon radar-mapped -100m

Mars radar-mapped – 20m

Venus radar-mapped – 100m

USS San Francisco Accident

GeoTimes

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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 Leonesio.

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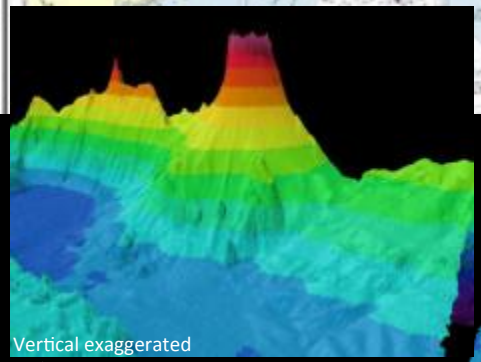
San Francisco Grounding Location Survey

SFO Grounding Survey Polygon



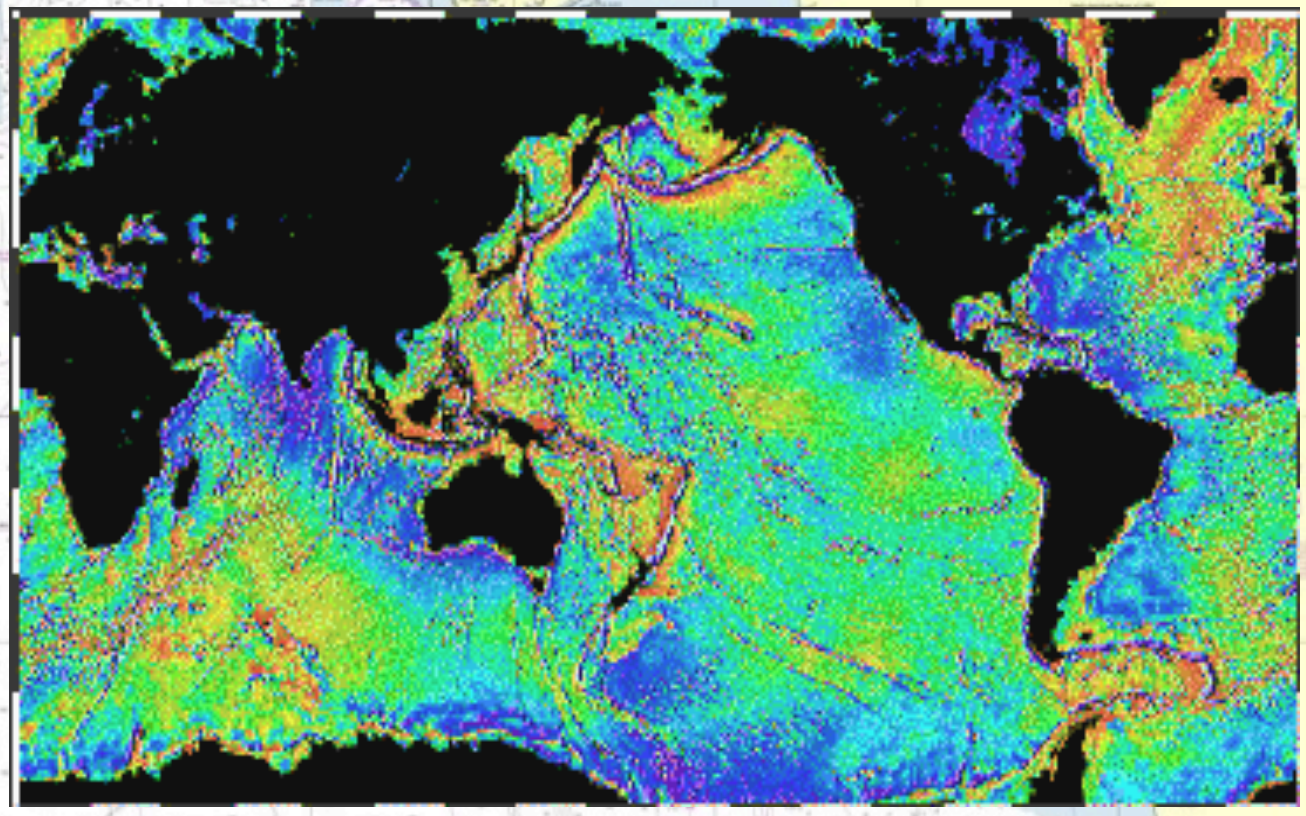
SFO Grounding

New feature

Approved for Public Release Naval Oceanographic Office 2011

Maritime Defense and Security

Bathymetric Model from Satellite Altimetry



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

Resources

- IHO www.iho.int
  - Publications https://www.iho.int/iho_pubs/IHO_Download.htm
- NOAA Office of Coast Survey https://www.nauticalcharts.noaa.gov/index.html
  - Hydrography pubs https://www.nauticalcharts.noaa.gov/hsd/hydrog.htm