UNESCO
Intergovernmental Oceanographic Commission

Indian Ocean Tsunami Information Centre

ESCAP
Economic and Social Commission for Asia and the Pacific

INCOIS

BMKG

Tsunami Ready

Optimizing ComMIT inundation runs - developing DEM grids, grid sizing, accuracy and robustness testing, instabilities, and model parameters

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TEMPP 2025

Training Workshop on Tsunami Evacuation Plans, Maps, and Procedures (TEMPP) and UNESCO-IOC Tsunami Ready Recognition Programme (TRRP) for Indian Ocean Member States

ITCOOcean, INCOIS, Hyderabad
15-23 April 2025

COASTAL DEM DEVELOPMENT
BEST PRACTICES

COASTAL DEM DEVELOPMENT BEST PRACTICES

NOAA's National Geophysical Data Center (NGDC) builds and distributes high-resolution, coastal digital elevation models (DEMs) that integrate ocean bathymetry and land topography to support NOAA's mission to understand and predict changes in Earth's environment, and conserve and manage coastal and marine resources to meet our Nation's economic, social, and environmental needs. DEMs should be as accurate as possible to minimize error in the modeling of coastal processes. Good practices throughout DEM development help to ensure this.

http://www.ngdc.noaa.gov/mgg/coastal/coastal.html

STRATEGY: Plan Ahead

1. Determine the purpose of the DEM. DEMs have many uses (e.g., modeling of tsunamis, storm surges, or coastal currents), each of which may have specific requirements.
2. Select DEM parameters (extent, cell size, vertical datum, file format, etc.) that will best support the intended use.
3. Choose a gridding technique that will minimize errors when interpolating across large areas without data (see Fig. 1).
4. Collect data in an area larger than the DEM (see Fig. 1) to avoid anomalies along DEM edges.

check Search the Internet for DEMs of your study area to see if an existing one is suitable.

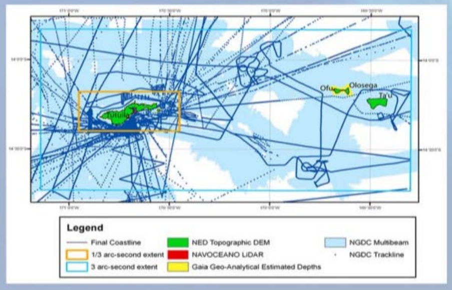


Fig 1. Pago Pago, American Samoa DEM data sources. Data were collected in an area 5% larger than DEM extents to prevent gridding edge effects. The DEM was also extended to encompass the smaller U.S. islands to the east. A second, higher-resolution DEM (orange box) was built where data are denser. White areas lack depth measurements.

STRATEGY: Know Your Data

1. Determine what data are available and carefully assess that data, so that you know their inherent problems and limitations.
2. Verify that metadata are correct.
3. Determine if data overlapped by newer surveys need to be eliminated. This may or may not be necessary depending upon if there has been significant morphologic change between the two survey years (see Fig. 2).

hint Review journal articles, company survey reports, and local government documents to find data sets in the region that are not accessible on the Internet.

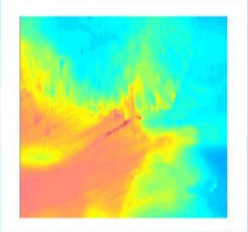


Fig 2. An example of anomalies created from overlapping and inconsistent data sets. More recent or higher-resolution data sets are usually more accurate, and the other data may need to be eliminated.

STRATEGY: Pay Attention to Detail

1. Organize your file structure to help keep track of file types, data edits, and datum conversions. This helps others review your work.
2. Double-check all data conversions and transformations for possible software or processing errors.
3. Determine how detailed your coastline needs to be, and what features should be included or excluded, such as piers (see Fig. 3).

to do Document all data sources and processing steps when building the DEM, so that users can reconstruct your work.

Fig 3. Example of varying coastline needs. Two coastlines were developed for the region surrounding the Los Angeles and Long Beach harbors. The red coastline does not include the large wharves resting on pilings and was used to build an intermediate model of seafloor relief. The white coastline, which includes the wharves, was used to clip the seafloor relief model and ensure that the wharves had positive elevation values in the final DEM.

Strategy: Convert to Common Datum

1. Convert all data to a common horizontal datum and file format, so that overlapping data sets can be directly compared to each other.
2. When necessary (i.e. when the cell size is small, 30 meters or less), convert data to a common vertical datum to minimize anomalies along the coastline.
3. Where available, use VDatum (http://vdatum.noaa.gov/) to convert between vertical datums. Otherwise, use datum offsets measured at local tide stations (http://tidesandcurrents.noaa.gov/).

check Look for inconsistencies between overlapping data sets, especially along the boundaries of data sets.

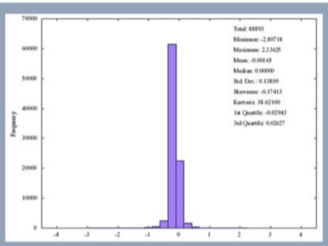


Fig 4. A histogram comparing a source data set's elevations with the DEM. Large discrepancies need to be evaluated to determine their origin.

Strategy: Thoroughly Evaluate DEM

1. Statistically compare DEM cell elevations with source data sets to ensure that the DEM accurately represents source elevation values (see Fig. 4).
2. Visually compare the DEM with satellite images, topographic maps, nautical charts, and aerial and personal photographs to ensure that the DEM represents current morphology (see Fig. 5).
3. Compare DEM cell elevation values with independent measurements of elevation that were not used in DEM development, such as geodetic monuments (http://www.ngs.noaa.gov).

hint Search the Internet for personal photographs of your study area. They may show coastal morphology and be useful for visually evaluating your DEM.

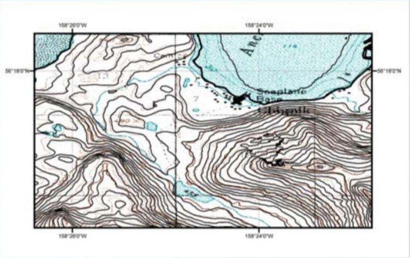
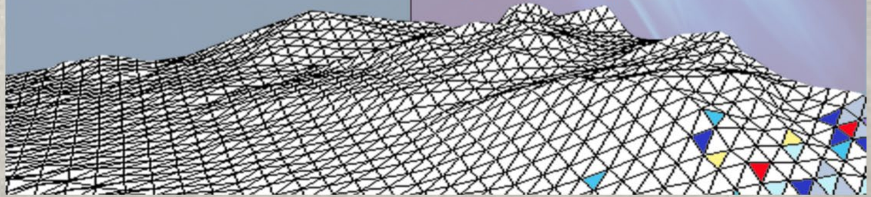


Fig 5. Comparison of DEM contours with a georeferenced USGS topographic contour map. Areas where the two contour sets diverge may indicate changes in morphology or errors in the DEM.

FOR MORE INFORMATION CONTACT:

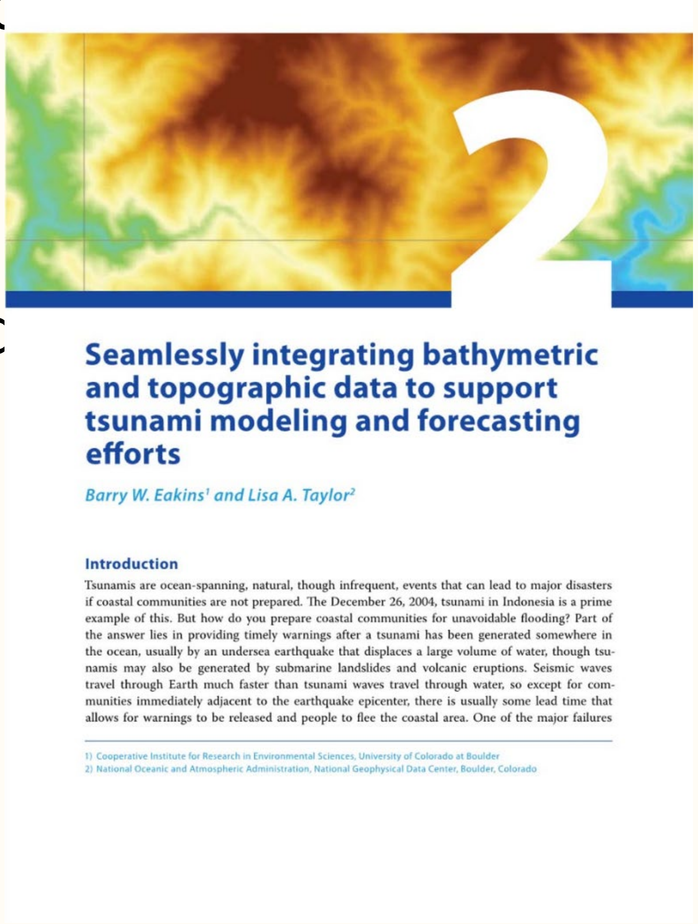
NOAA National Geophysical Data Center
325 Broadway E/GC3
Boulder, CO 80305-3328 USA

Phone: 303-497-6826
Fax: 303-497-6513
TDD: 303-497-6958
Email: dem.info@noaa.gov
Web: http://www.ngdc.noaa.gov/mgg/coastal/coastal.html



Summary

- Bathymetric and topographic data sc
- Data quality control
- Techniques and tools for compiling c
- Creating and refining model grids



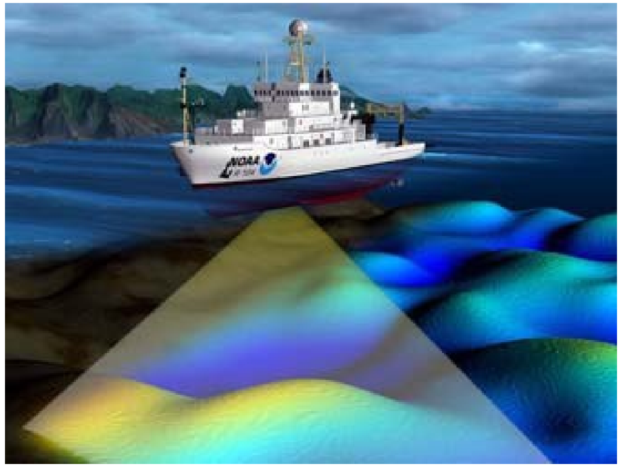
Seamlessly integrating bathymetric and topographic data to support tsunami modeling and forecasting efforts

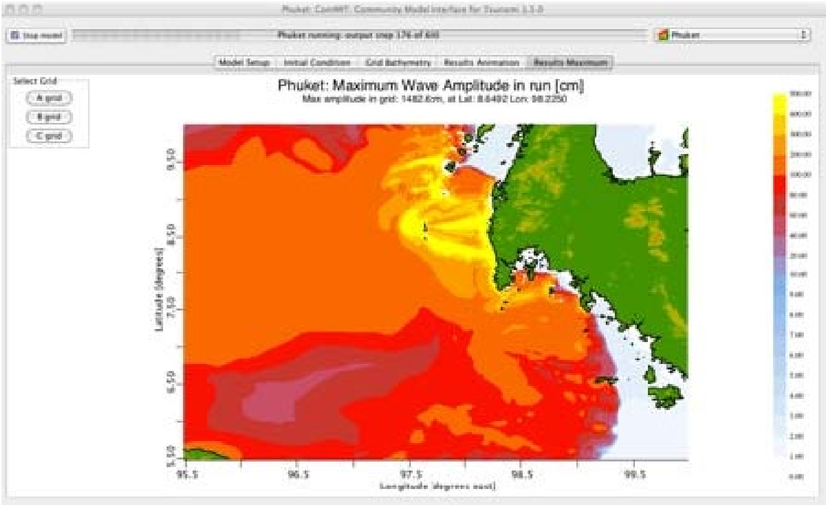
Barry W. Eakins[1] and Lisa A. Taylor[2]

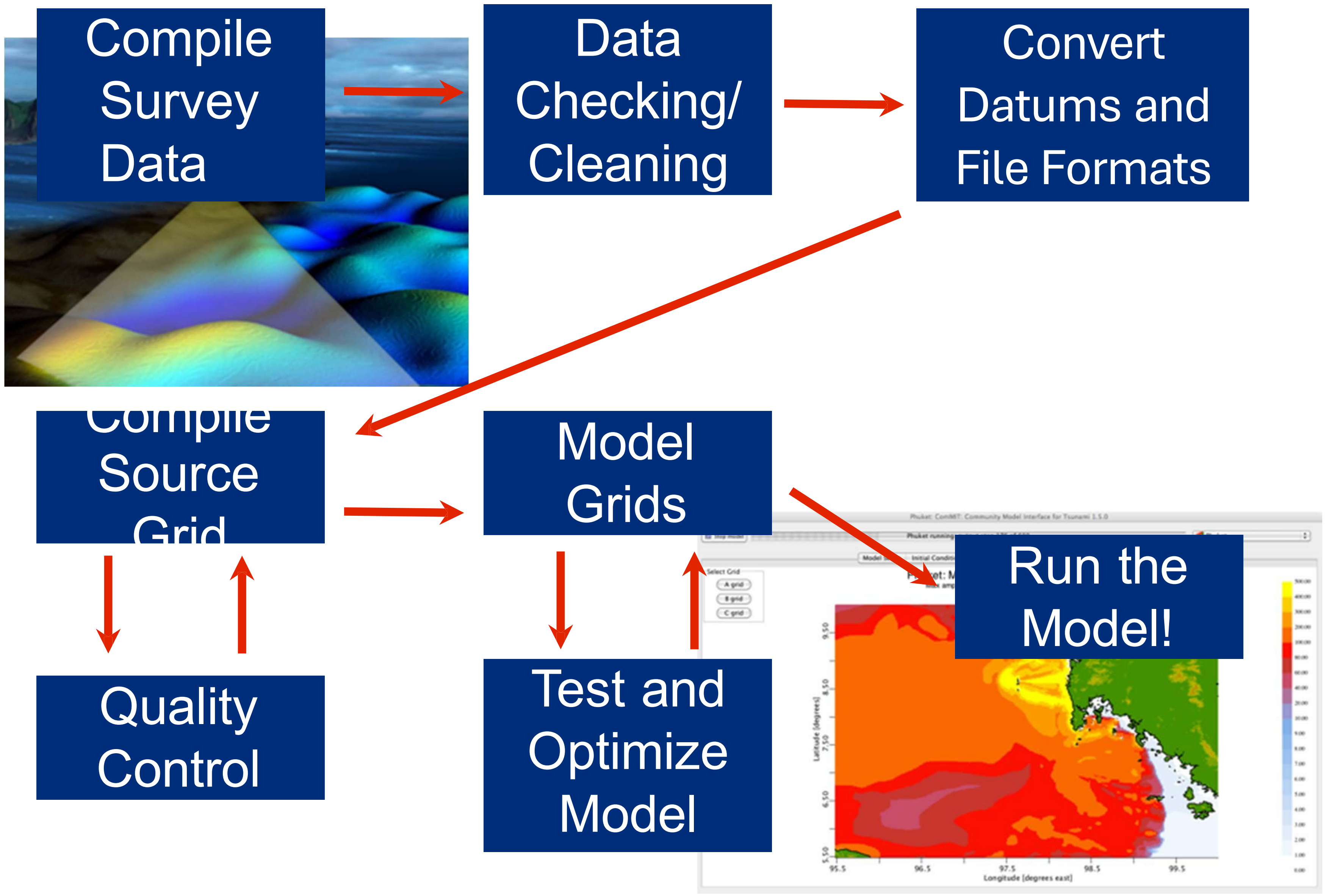
Introduction

Tsunamis are ocean-spanning, natural, though infrequent, events that can lead to major disasters if coastal communities are not prepared. The December 26, 2004, tsunami in Indonesia is a prime example of this. But how do you prepare coastal communities for unavoidable flooding? Part of the answer lies in providing timely warnings after a tsunami has been generated somewhere in the ocean, usually by an undersea earthquake that displaces a large volume of water, though tsunamis may also be generated by submarine landslides and volcanic eruptions. Seismic waves travel through Earth much faster than tsunami waves travel through water, so except for communities immediately adjacent to the earthquake epicenter, there is usually some lead time that allows for warnings to be released and people to flee the coastal area. One of the major failures

1) Cooperative Institute for Research in Environmental Sciences, University of Colorado at Boulder
2) National Oceanic and Atmospheric Administration, National Geophysical Data Center, Boulder, Colorado


NOAA


Model Setup
Initial Condition
Grid Bathymetry
Results Animation
Results Maximum
Select Grid
A grid
B grid
C grid
Phuket: Maximum Wave Amplitude in run [cm]
Max amplitude in grid: 1482.6cm, at Lat: 8.6492 Lon: 98.2250
Latitude [degrees]
95.5
96.5
97.5
98.5
99.5


Compile Survey Data
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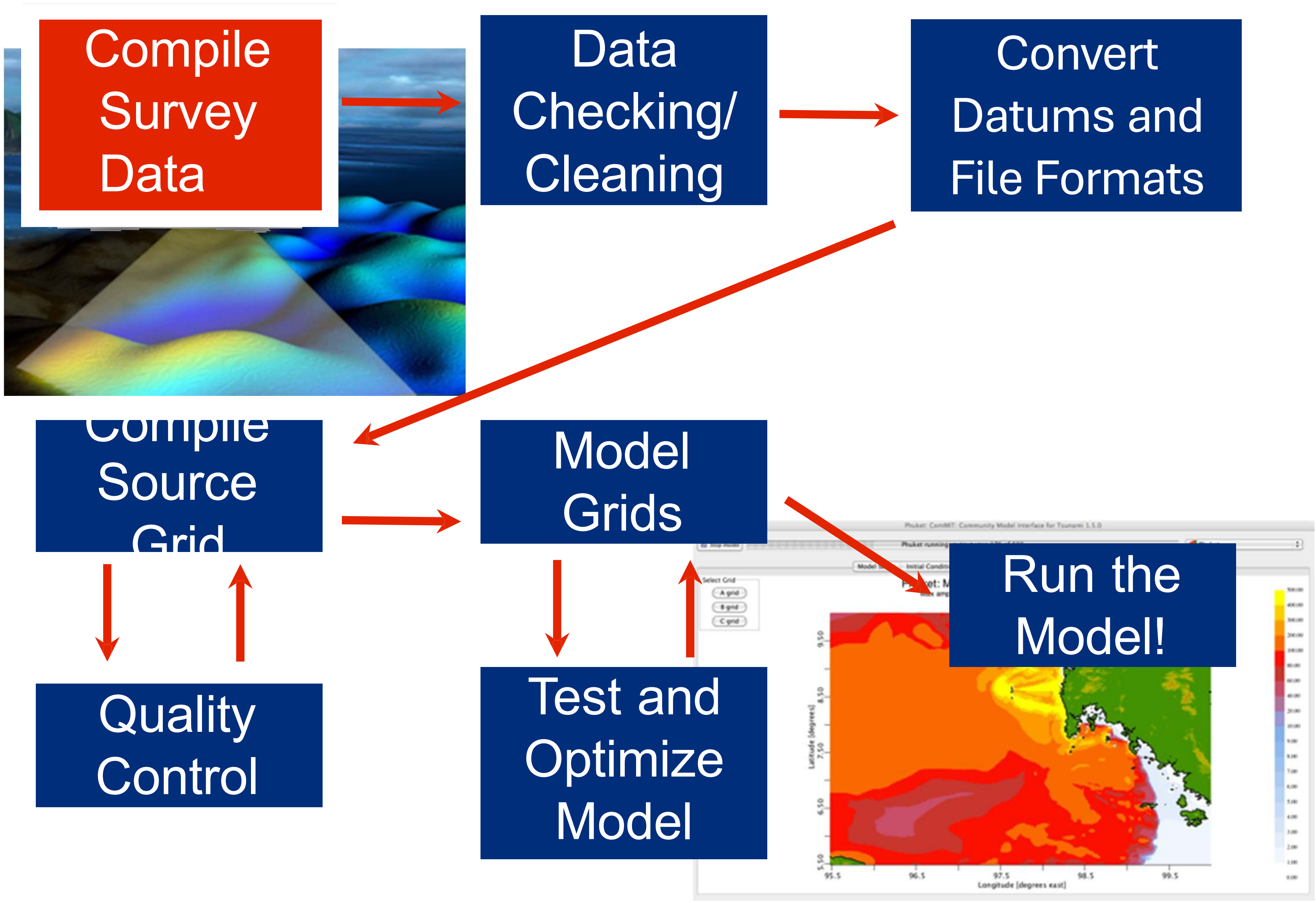
Model Grids
Run the Model!
Quality Control
Test and Optimize Model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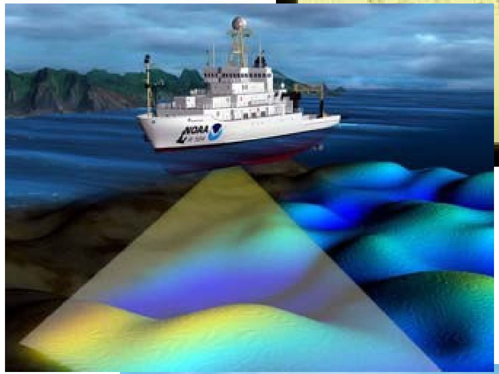
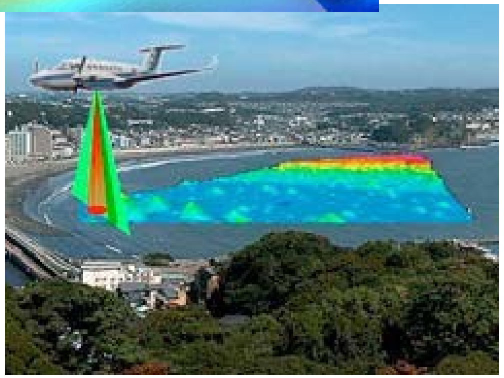
Bathymetric Survey

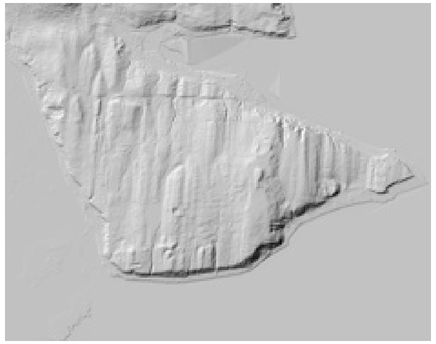
- Singlebeam survey
- Multibeam surveys
- Bathymetric LiDAR

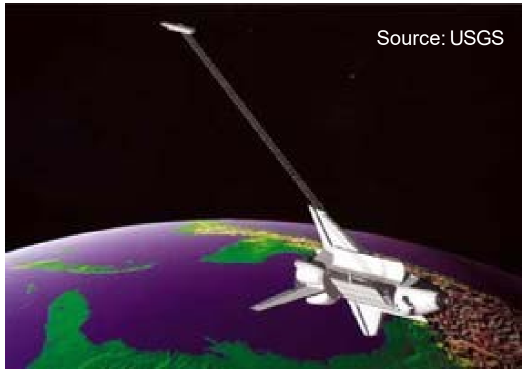




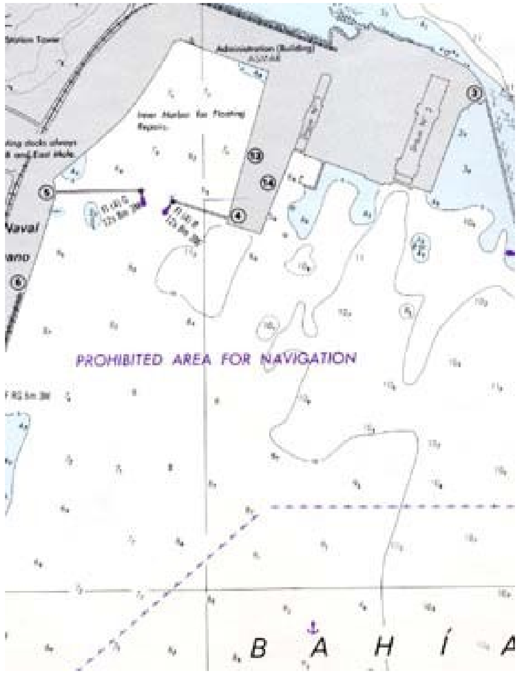
Topographic Survey

- Leveling
- Photogrammetry
- Topographic LiDAR
- Space-based Radar (SRTM)




Source: USGS

Other Data Sources



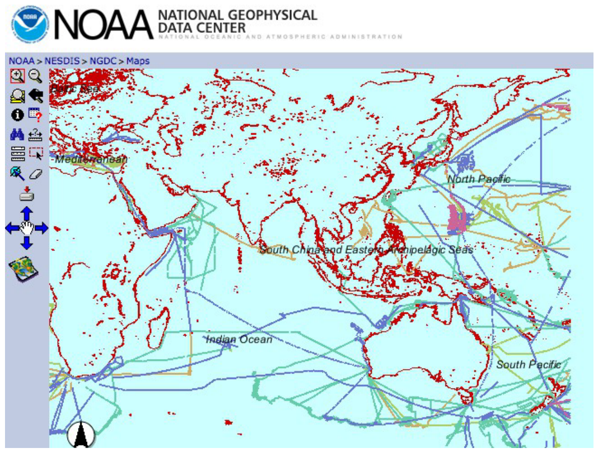
- Chart soundings and contours
- Topographic maps
- Aerial and satellite photography
- Engineering and scientific reports

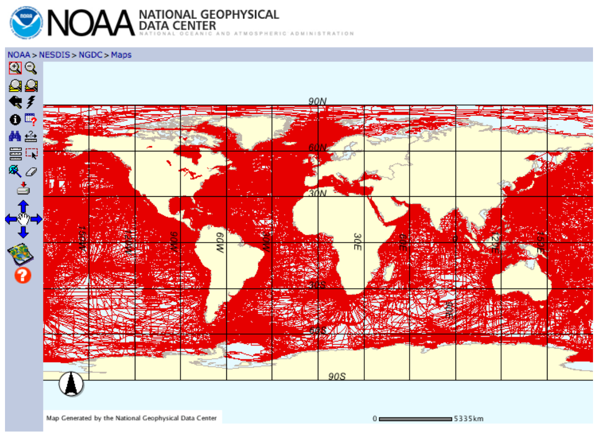
Online Global Data

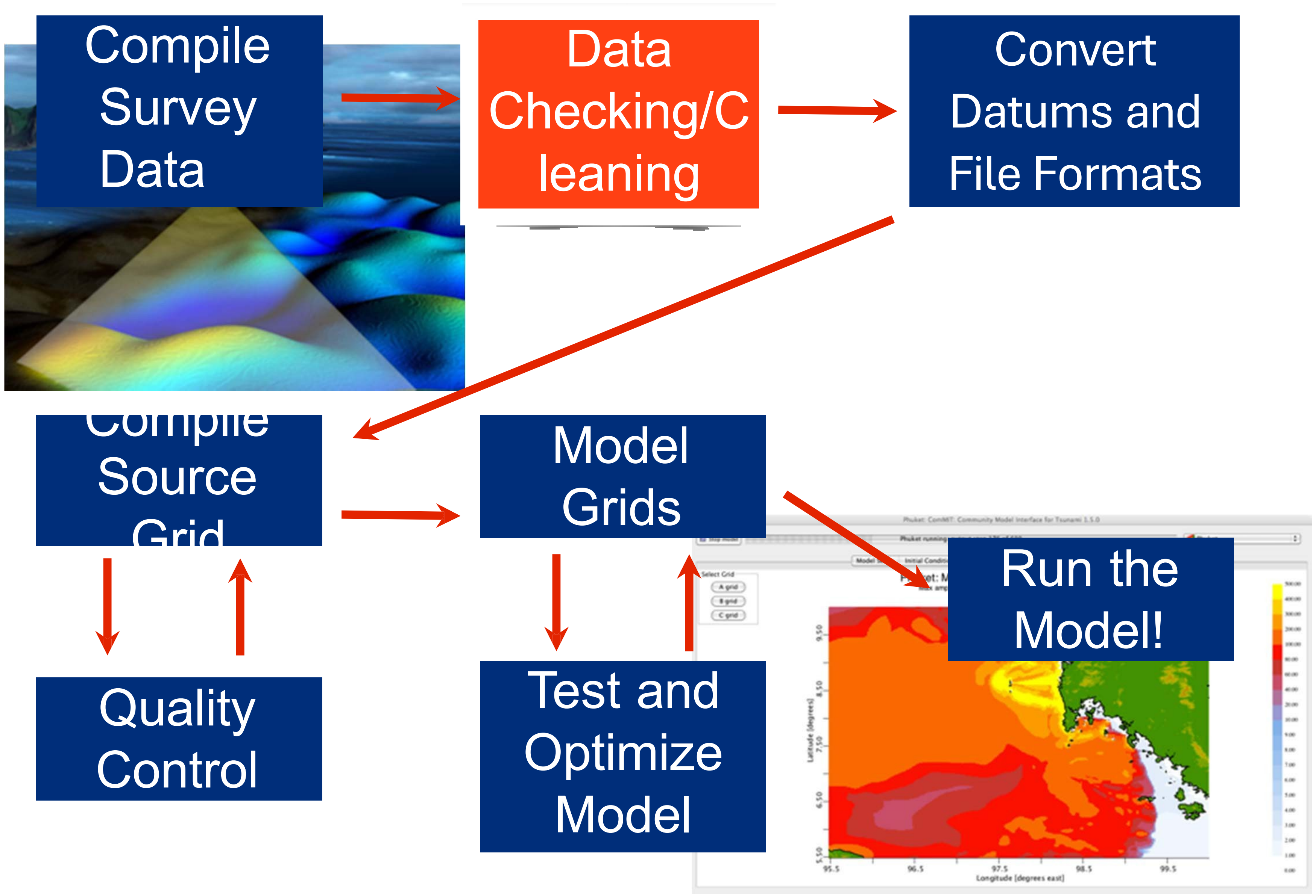
- ETOPO1
  - Global bathymetry and topography at 1 arc-minute
  - http://www.ngdc.noaa.gov/mgg/global/global.html
- Shuttle Radar Topography Mission (SRTM)
  - 3 arc-second (~90m) global topography
  - http://srtm.csi.cgiar.org/
  - http://srtm.usgs.gov/

Online Global Data

- National Geophysical Data Center (USA)
  - http://ngdc.noaa.gov/
  - Multibeam surveys
  - Track lines
- International Hydrographic Organization
  - http://www.iho-ohi.net/english/world-bathymetry/



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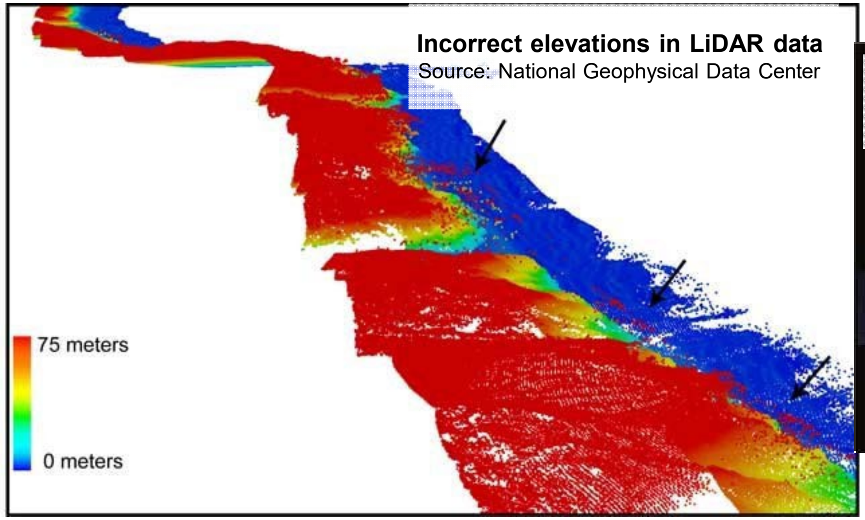
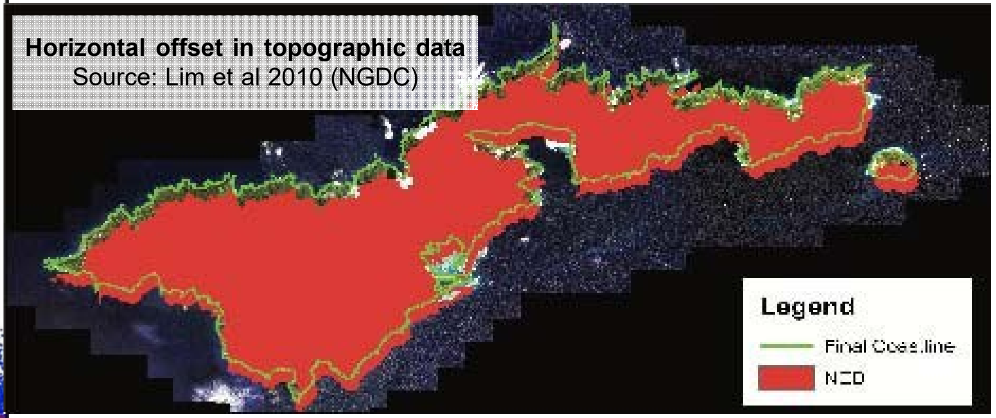
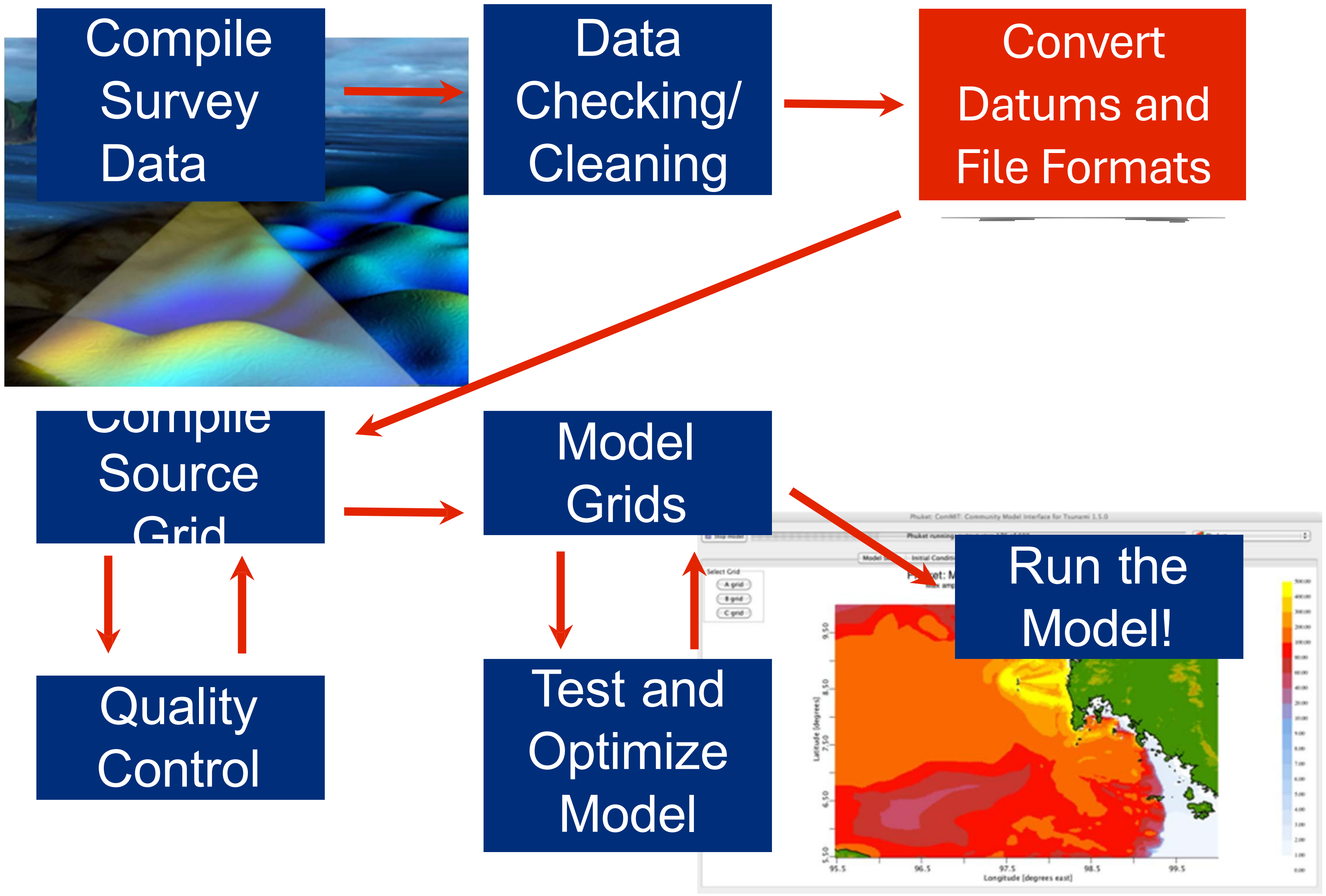
Data Quality Control

Check datasets before compiling grid

Bad depths? Bad locations?



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Horizontal Datum

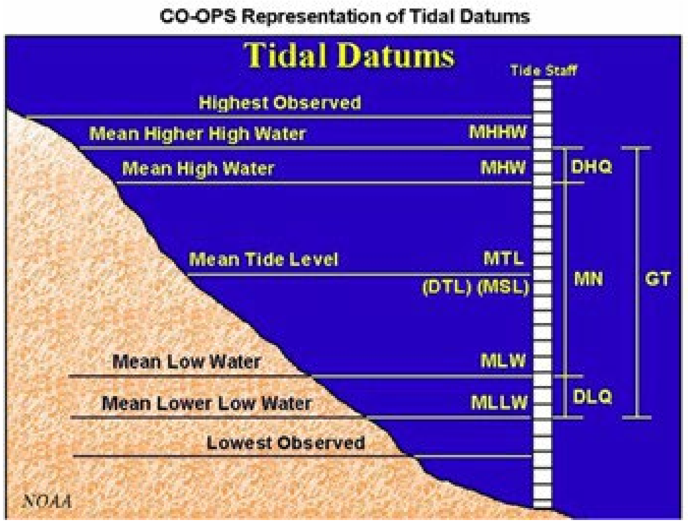
All data must be relative to the same datum!

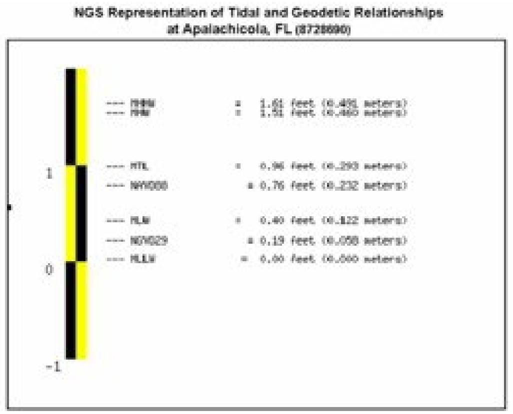
- Datum: description of the shape and size of the earth, and location of the zero point
- Our models use:
  - WGS 84 datum
  - Decimal degree coordinate system
- Reproject and change datums of data with GIS or PROJ.4.

Vertical Datum

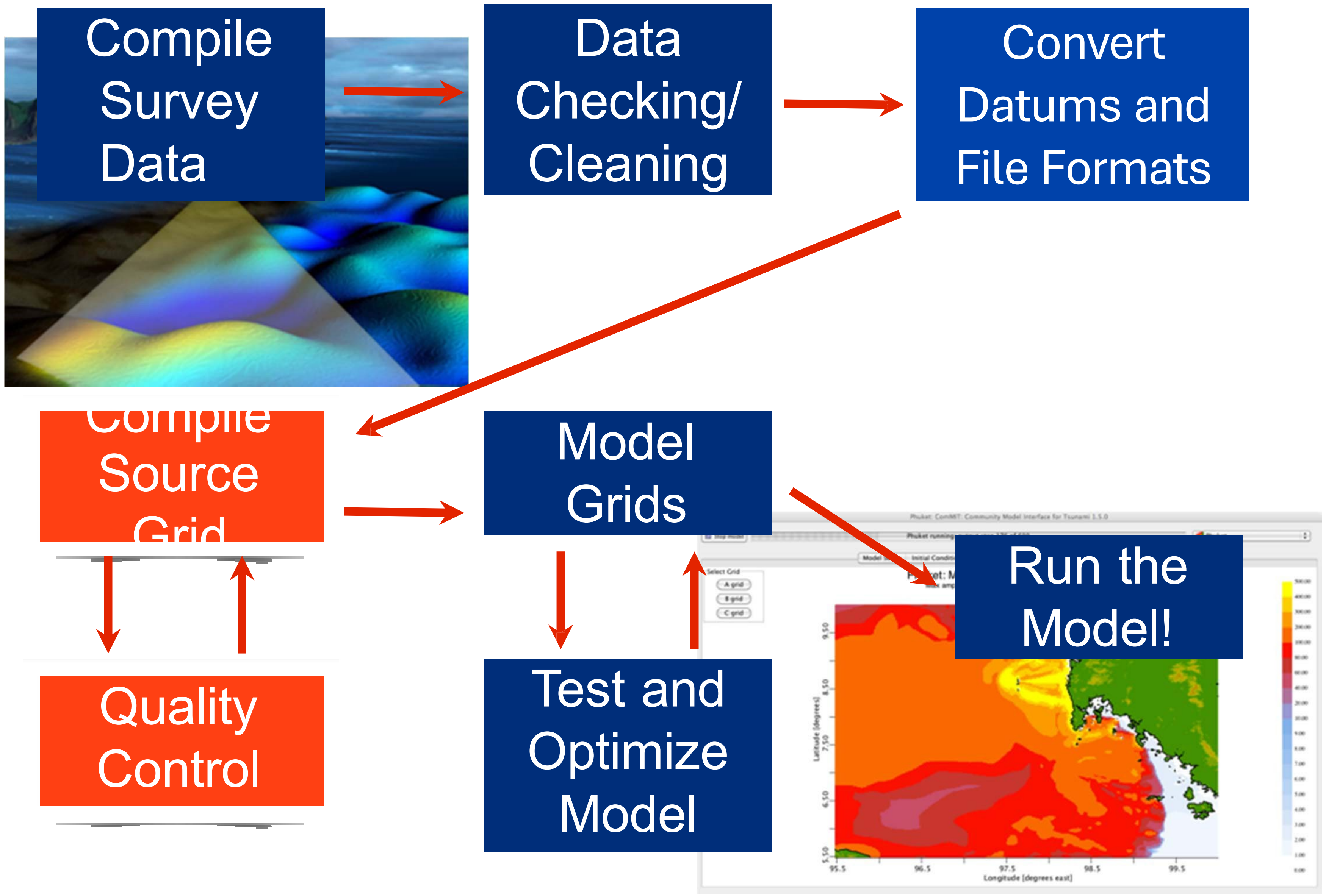
All data must be relative to the same datum!

Source: NOAA NOS CO/OPS





- Add or subtract depth values to make their zero point (datum) the same
- Our models use the mean high water datum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Compile Source Grid

- Source grids provide a starting point for developing model grids
- Use the highest resolution that is supported by your data
    - 1 arc-minute (30 m) or less if possible

Tools for Grid Development

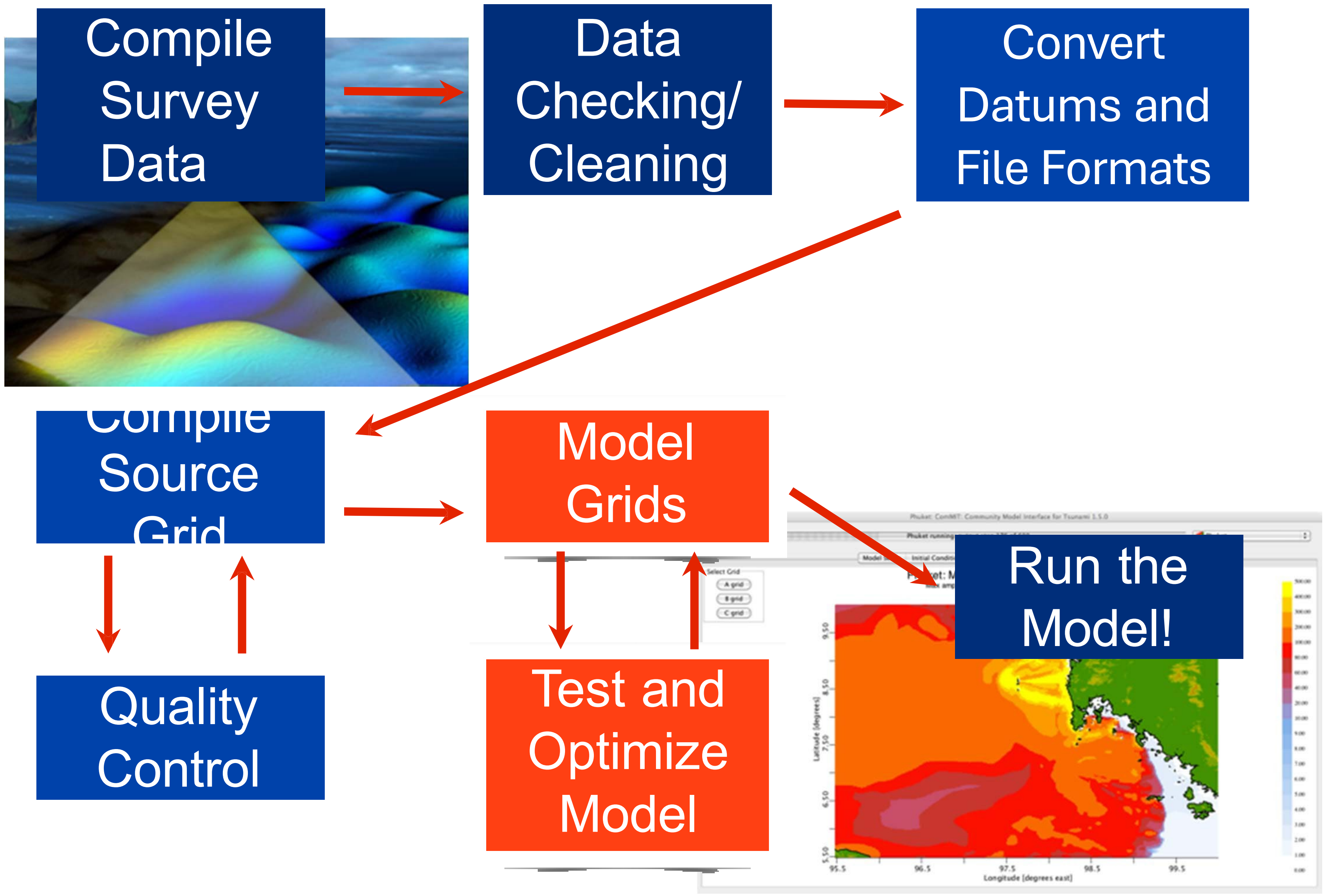
- GIS software
  - ArcGIS: helpful but expensive
  - Open source options: GRASS, QGIS
- MBSystem
  - Reads most native multibeam file formats plus xyz point data
  - Handles very large datasets very well
  - Open source: http://www.ldeo.columbia.edu/res/pi/MB-System/
- Matlab

Sample Grids for Training

- Data quality suitable for testing and training, but *not* for final products
- Automatically generated from public sources:
  - ETOPO1 bathymetry
  - SRTM topography
- 3 arc-second (~90 m) grid cell size
  - Bathymetry interpolated from 1 arc-minute source

Sample Grids for Training

Available in ComMIT: Model→New Model Run.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Model Grids: Extent

- Determine the outline of your study area
- This version of ComMIT & MOST always uses three nested grids
- Try to include major features that might affect wave dynamics: islands, bays, shoals
- If possible, outermost (A) grid should extend to 1000 m depth contour

Model Grids: Extent

- Grid size (number of nodes) has a major impact on the model running time
- The ComMIT Server will not produce grids larger than 160,000 (400x400) nodes

Model Setup: Parameters

See the ComMIT Help menu for a summary of the model parameters

The MOST manual has complete details.

0.0010	Minimum amp. of input offshore wave (m)
5.0	Minimum depth of offshore (m)
0.1	Dry land depth of inundation (m)
0.0009	Friction coefficient (n^2)
☑	Let A-Grid and B-Grid run up
300.0	Max eta before blow-up (m)
1.20	Time step (sec)
40000	Total number of time steps in run
9	Time steps between A-Grid computations
3	Time steps between B-Grid computations
27	Time steps between output steps
0	Time steps before saving first output step
1	Save output every n-th grid point

Model Grids: Cell sizes and file formats

- Common model grid cell size for *forecast modeling* with MOST
  - A grid: 2 arc-minute
  - B grid: 30 arc-second
  - C grid: 3 arc-second

→ Models for hazard assessment may use smaller cell sizes - if the source data allows

- Grid cell size: ↓
  Maximum model time step (dt): ↓
  Model run time: ↑

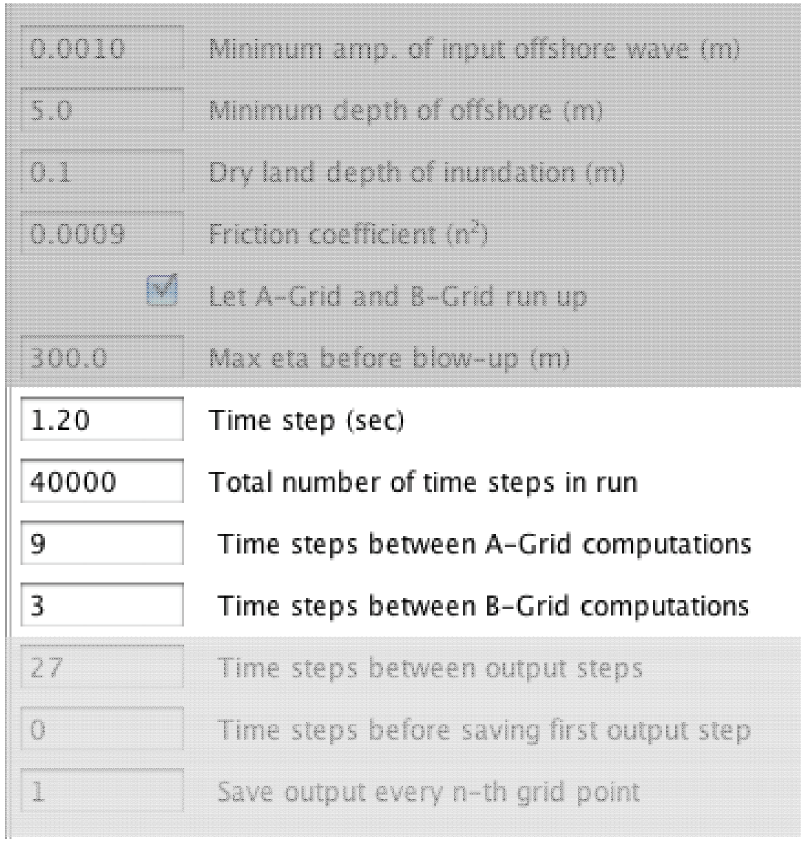
Model Grids: file Format

- ComMIT and MOST can use two formats for bathymetry grids:
  - “MOST format” (see the MOST manual PDF)
  - ESRI ASCII raster
- Model output is always in NetCDF

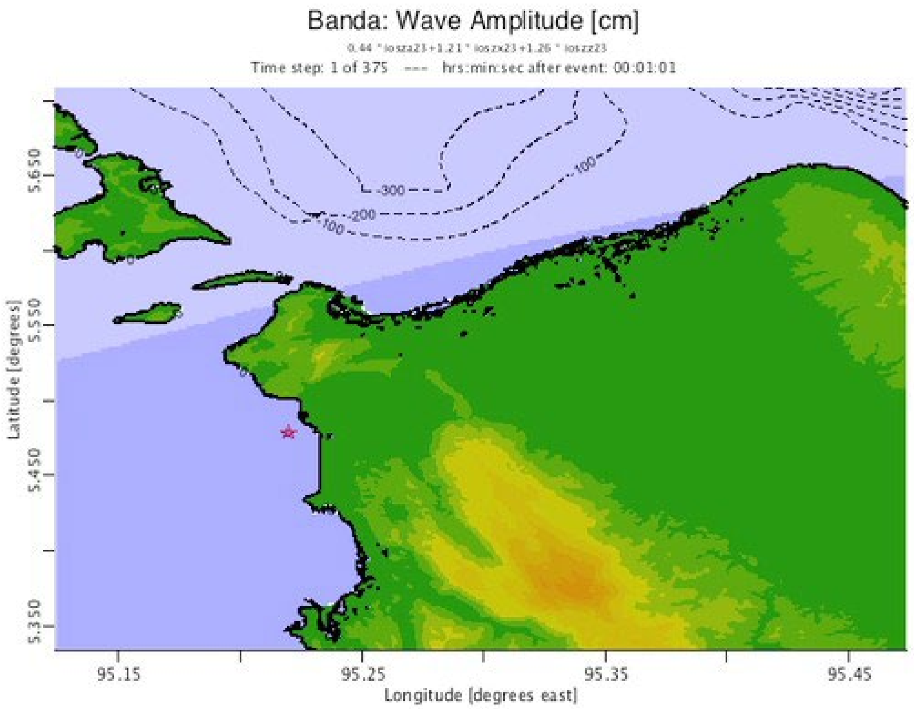
Model Setup: Parameters

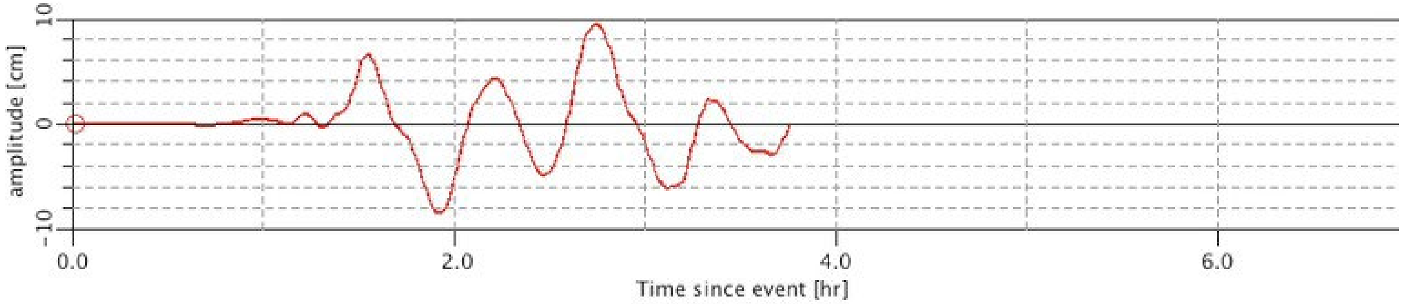
Most important parameters:

- Time step
- Total number of steps in run
- Time steps between A/B grid



Model Testing: Stability

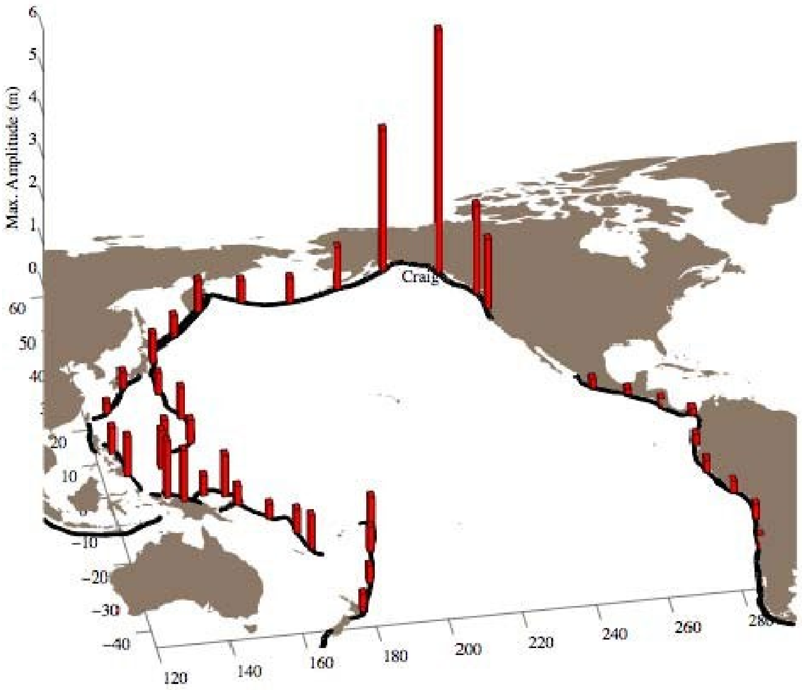




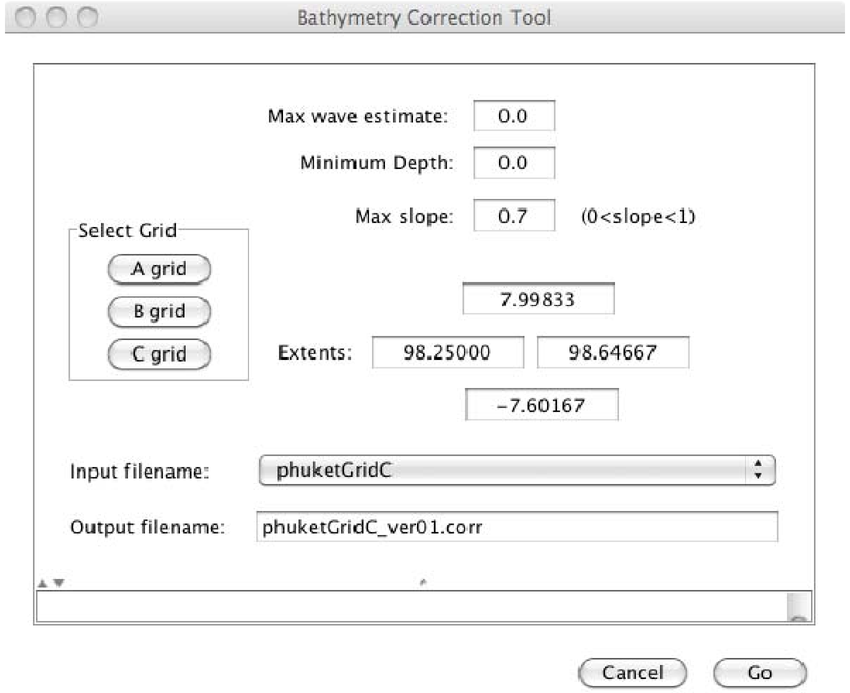
Model Testing: Stability

The model must be stable (no "blow ups") under any reasonable source scenario

Use large and small events

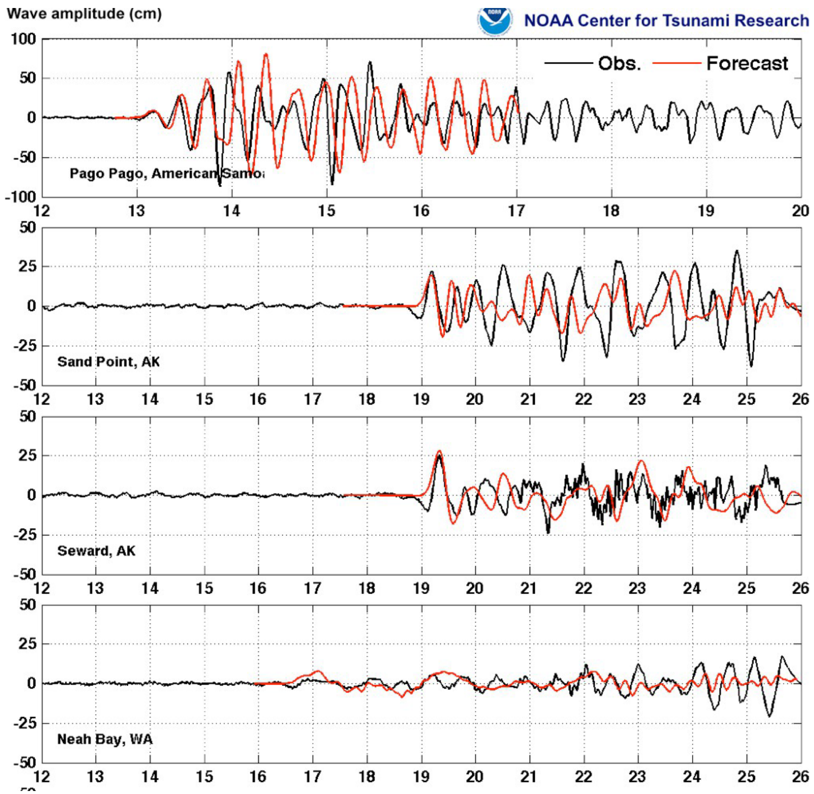


ComMIT's Smooth Bathymetry Tool can help



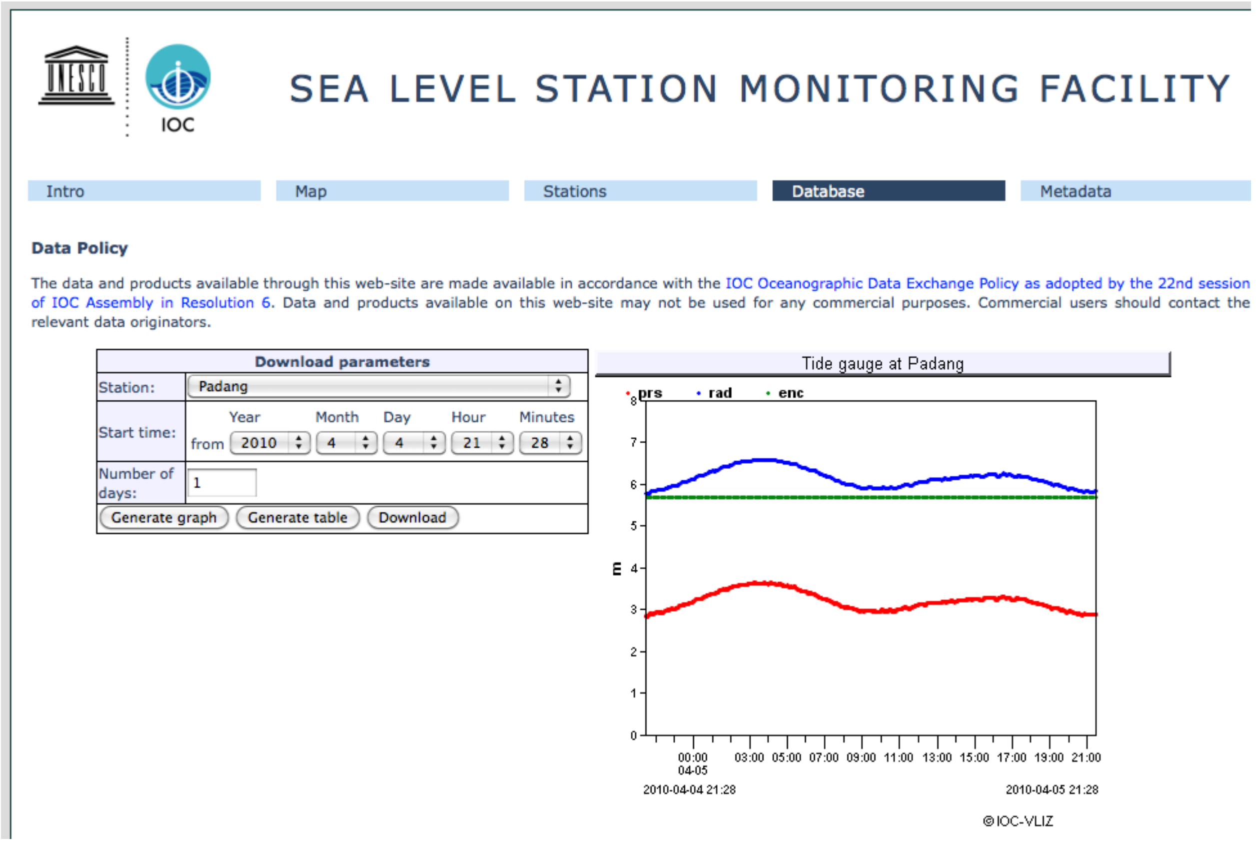
Model Testing: Accuracy

The model must accurately forecast real tsunami events



Model Testing: Accuracy

Sea level data for comparison:
http://www.ioc-sealevelmonitoring.org/



Tools for Grid Processing

- Matlab
  - NetCDF support: Matlab 2009+, or use mexnc for older versions.
- Some things that are useful:
  - Crop
  - Resample/regrid
  - Plotting tools
- ComMIT's Smooth Bathymetry tool

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Model Grids

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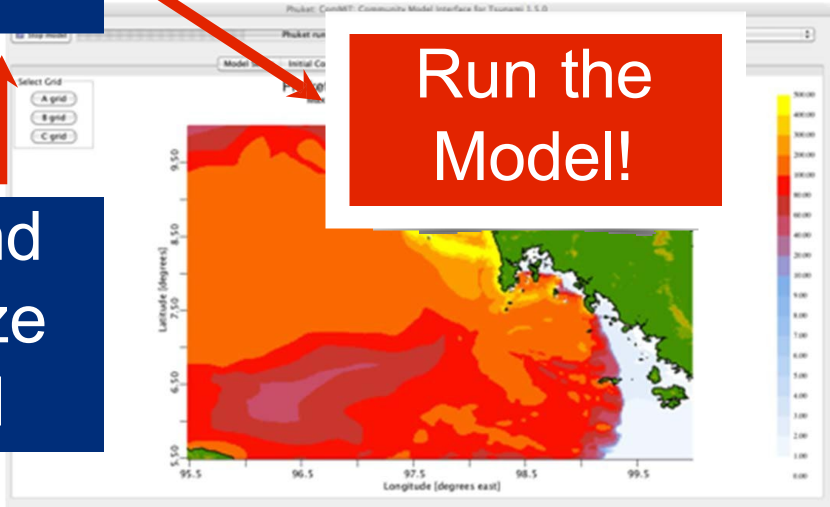
Test and Optimize Model



Run the Model!