Elevation Data in Coastal Zone: Accuracy, Scale, and Resolution

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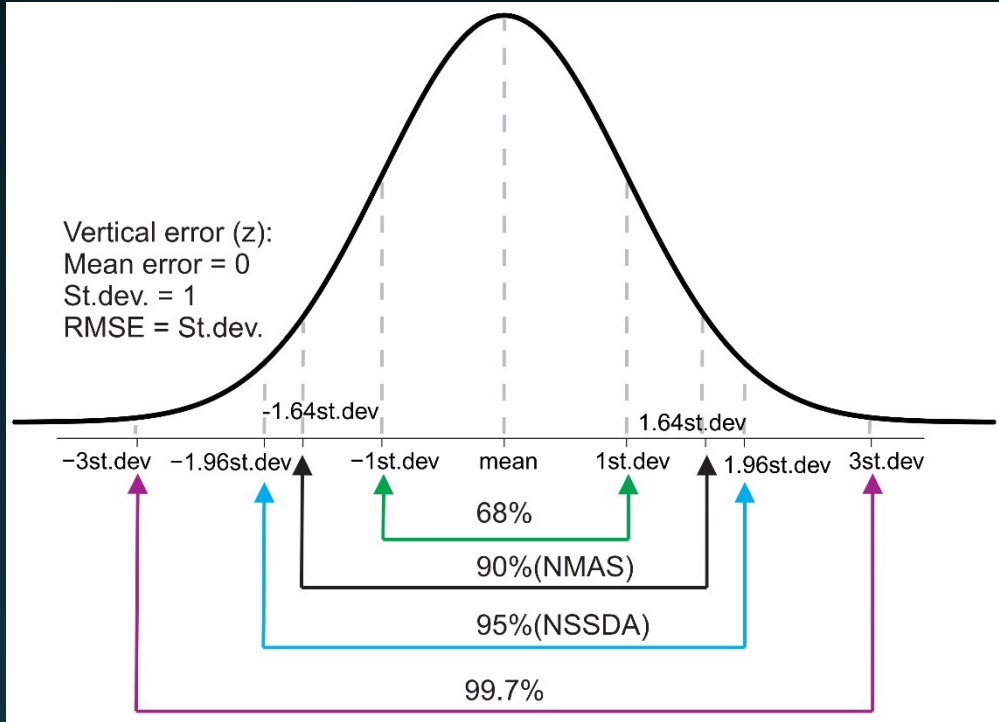
Mapping Matters:

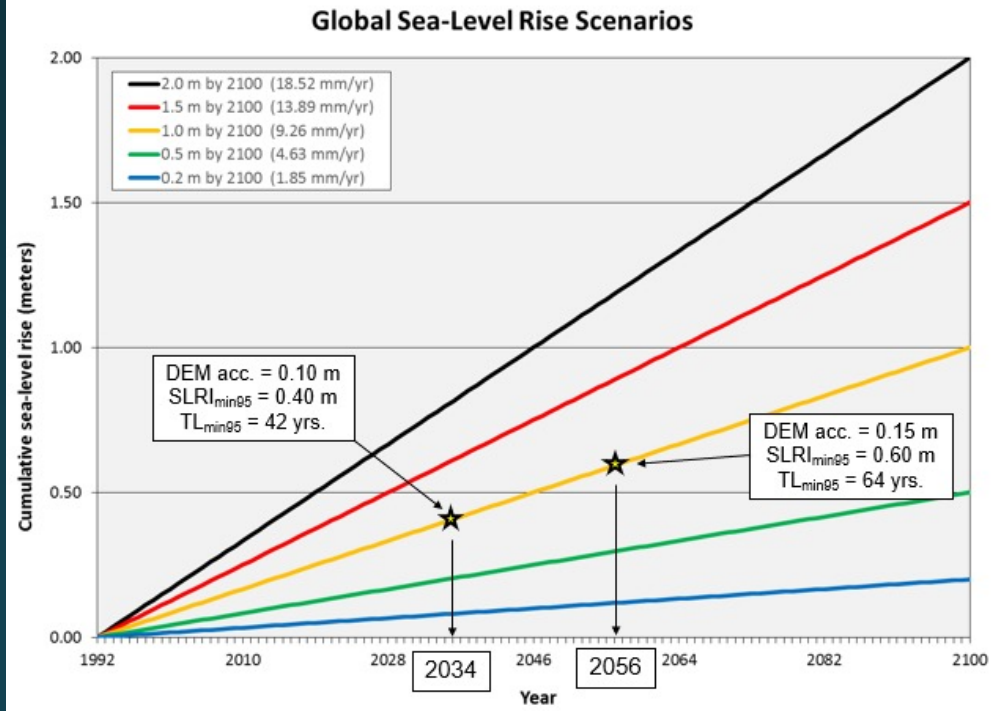
1. Accuracy / Uncertainty

- Qualitative vs. quantitative
- National Map Accuracy Standard (NMAS, 1941)
  - No more than 10% shall have an error greater than ½ of the contour interval at 90% C.I.
  - VMAS = 1.6449 * RMSE(z)
- ASPRS standards (1990)
  - Minimum RMSE no more than 1/3 of the contour interval at 90% C.I. (Class 1 map)
- National Standard for Spatial Data Accuracy (1998)
  - Acc(z) = 1.96*RMSE(z)



1a. Purpose

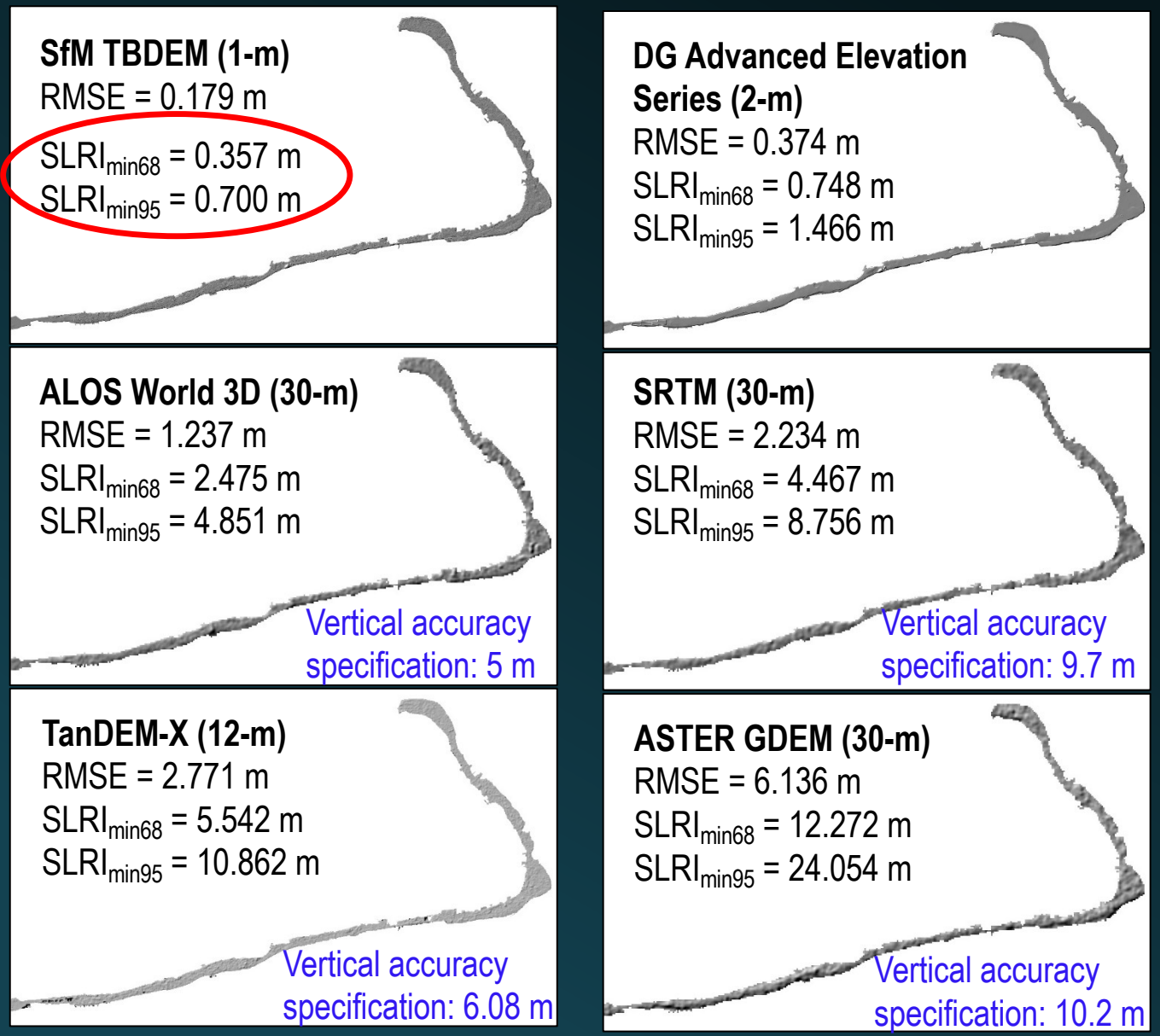
- What is the smallest increment of water level inundation
  - A contouring operation on a DEM
  - SLRI(min) = DEM accuracy * confidence interval factor(CIF): 2 for 68% C.I.; 3.29 for 90% C.I.; 3.92 for 95% C.I.
- What is the minimum Planning Timeline (TL(min))
  - The time interval required (at a given SLR rate) for the cumulative SLR to reach the minimum water level increment afforded by the elevation data
  - TL(min) = SLRI(min) / annual SLR rate
- What is the minimum significant topographic change



Coastal Assessment Questions

- What is the DEM accuracy required to model potential impacts of xx cm of SLR / water level inundation? (e.g., a given storm surge on top of x cm of SLR)
- For a given DEM with a vertical accuracy of xx cm, what is the minimum SLR increment or water inundation level that can be effectively modeled?
- What vertical accuracy is needed for elevation data to map the potential impact zone at 95% C.I. for xx cm of cumulative SLR by year 20xx?
- What is the cumulative DEMs accuracy required to model xx cm of significant topographic change?

Majuro Atoll, RMI



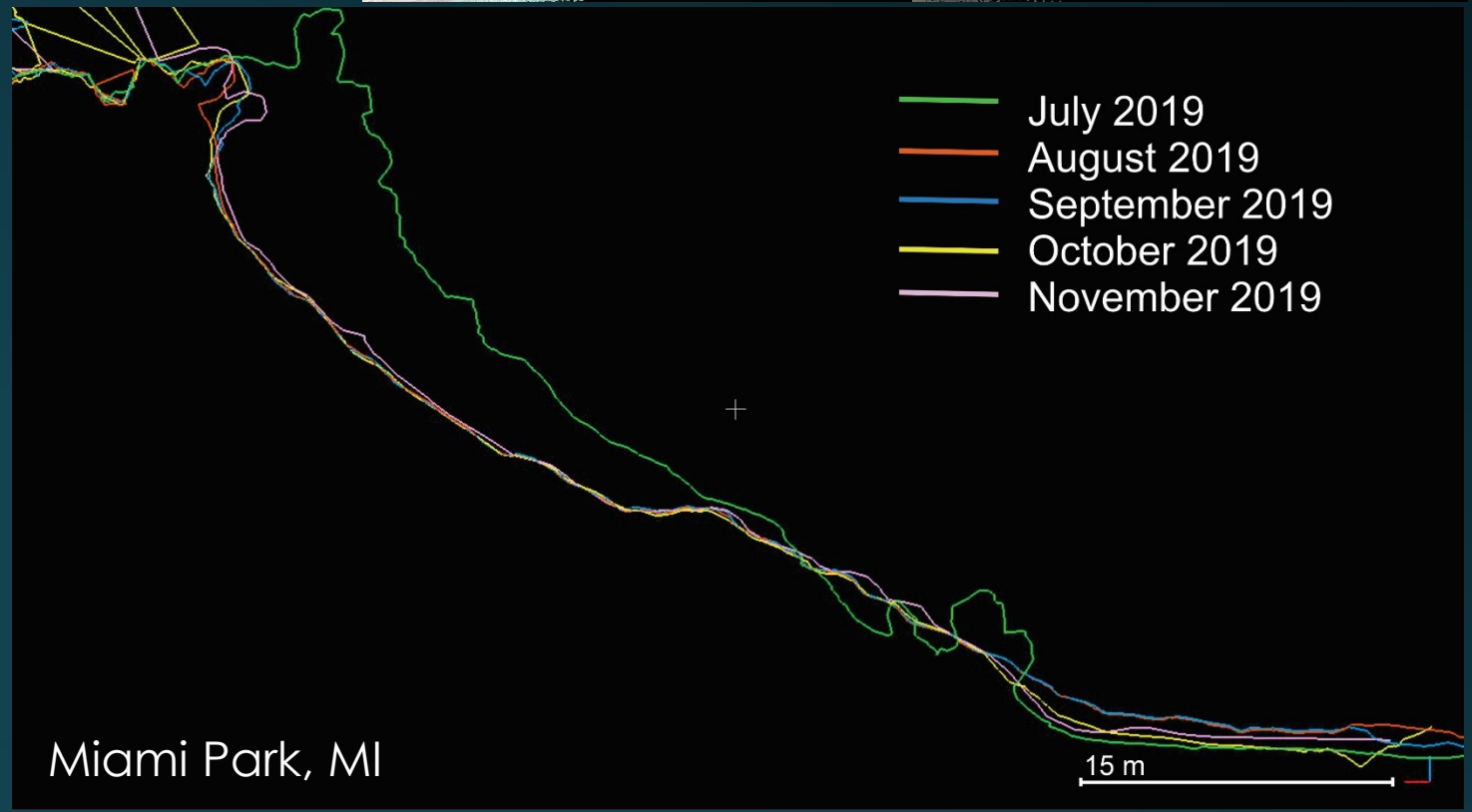
Gesch, D., Palaseanu-Lovejoy, M., Danielson, J., et al., 2020, Inundation Exposure Assessment for Majuro Atoll, Republic of the Marshall Islands Using A High-Accuracy DEM, *Remote Sensing*, https://doi.org/10.3390/rs12010154

Mapping Matters:
2. Resolution / Scale

- Global DEMs
  - Commercial: ~10 m
  - Free license, public domain: 30-m, 12 – m
- Regional and national scale:
  - Commercial: Stereo satellite imagery & lidar 1-m, 2-m
  - Free license, public domain: 3-m (NED), 10-m
- Local / site scale:
  - Commercial and free license, public domain: stereo satellite imagery, lidar, SfM 1-m, cm-scale

2a. Purpose

- What is the smallest feature we can identify at a certain DEM resolution?
  - Morphology scale: landslides, dunes, bluffs, slope, beach, sediment budget, etc.
- What is the minimum significant topographic change?
  - Vertical vs. horizontal



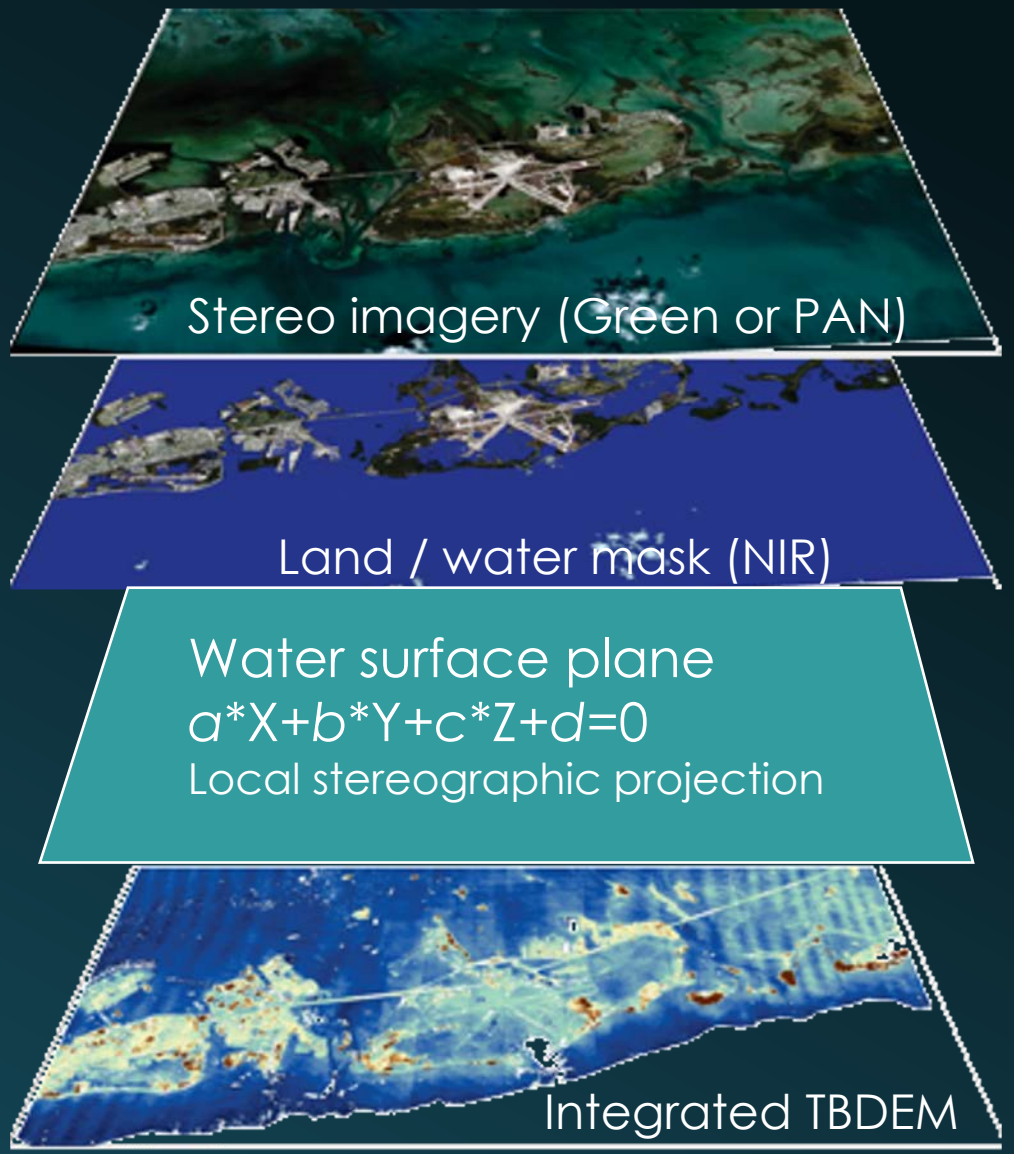
Topo-bathymetry (TBDEM)

- Bathymetry: water depth or underwater terrain elevation
- Bathymetry: Approximately 40% of the U.S. exclusive economic zone and about 4% of the Great Lakes have high-resolution bathymetric data available, and globally about 80% of the oceans were mapped at the rather coarse resolution of hundreds of meters (Westington et al.,2018)
- Global topo-bathymetry (TBDEM)
- Challenge: Integrating topography and bathymetry: majority of bathymetric data are depth soundings relative to a certain water level datum
- Coarse:
  - 30 arc-second grid (~ 1 km) SRTM30+
  - 15 arc-second grid (~450 m) (SRTM15+, GEBCO-2023, SEABED 2030)
  - 1/16 arc minutes (~115 m) (EMODnet-Bathymetry)
- Near shore and coastal processes require high quality bathymetry and / or TBDEM data
  - Topo-bathymetric lidar (1-m, max 40 - 50 m depth)
  - Satellite derived bathymetry(SDB, 30-m, 10-m, 2-m, 1-m, max 20 to 40 m depth) and / or stereo satellite derived TBDEM (1-m, 2-m, max 10 to 30 m depth)
- Local / regional TBDEM (1-m, 3-m)
  - USGS Coastal National Elevation Database (CoNED) Applications Project

SDB and SD-TBDEM

- Satellite derived bathymetry
  - ~ 5 decades of development
  - Landsat archive became freely available in 2008 and Sentinel-2A in 2015
  - Methods developed by Stumpf et al. (2003) and Lyzenga et al. (2006)
  - Needs auxiliary bathymetry data: band ratio regression against some sample bathy data (soundings, lidar, ICESat-2)
  - Obtains only water depth
  - No comprehensive integrated open-source software
- Satellite derived TBDEM
  - Available integrated open-source software: SaTSeaD bathymetry module for NASA Ames stereo-pipeline(ASP)
  - Derives underwater terrain elevations, not water depths
  - No external bathymetry data necessary
  - Uses stereo imagery (PAN, Green, NIR)

TBDEM: NASA ASP with SaTSeaD



Palaseanu-Lovejoy, M.; Alexandrov, O.; Danielson, J.; Storlazzi, C. SaTSeaD: Satellite Triangulated Sea Depth Open-Source Bathymetry Module for NASA Ames Stereo Pipeline. Remote Sens. 2023, https://doi.org/10.3390/rs15163950

Wishlist and dreams

- What kind of spatial/temporal requirements do we need?
  - Coastal areas are very dynamic: seasonal changes, event driven, change order of cm to m
  - Coastal change can be ephemeral but important
- What would be game-changing for our specific applications, enabling entirely new possibilities?
  - What we want: Seasonal 1-m resolution TBDEM with up to 10 cm RMSE(z) (topo) and 15 cm RMSE(z) (nearshore bathy) for the nation
  - What is good enough: yearly and event driven 3-m resolution TBDEM
- What kind of data latency do we require?
  - As soon as possible - usually event driven
- What is our wish list beyond current capabilities?
  - High accuracy & temporally dense 1-m resolution TBDEM (up to 40 m depth)
  - Freely available stereo and multi-stereo satellite imagery with cloud masks
  - Spatially near-continuous satellite topo-bathy lidar
  - Open-source software at production level to process regional data efficiently
    - A nice user interface for NASA ASP to process both topo and TBDEMs
    - Add "real" multi-stereo-vision to NASA ASP (topo and TBDEM)
    - Enhanced capabilities: use of cloud masks; ICESat-2 for alignment
- What kind of product (level) would be most useful to us?
  - Stereo and multi-stereo imagery with cloud masks (we use 1B level DG)
  - 3-D data – point clouds with RGB colors (and classification)
  - High-resolution and accuracy raster TBDEM (with floating point elevation values)
  - Automatic metadata generation to include vertical RMSE, correct coordinate system and datum, processing parameters / decisions
  - Topographic change on demand: OpenTopography: On-Demand Vertical Differencing of USGS 3DEP and NOAA Lidar Topography (~20% of the contiguous United States)