Development of Puerto Rico and US Virgin Islands sea surface topography for vertical datum transformation using retracked altimetry and tide gauges

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A regional mean sea surface topography (TSS or mean dynamic topography) grid for Puerto Rico and US Virgin Islands (PR/VI) is developed as one component to assist with national vertical datum transformation capabilities within NOAA's VDatum Program.

NOAA's VDatum (https://vdatum.noaa.gov) is a comprehensive suite of tools for performing vertical transformations among a variety of tidal, orthometric and ellipsoidal vertical datums, allowing to convert geospatial data from different horizontal/vertical references into a common system.

For the PR/VI TSS, approximately 20 years of retracked altimetry data with custom geophysical corrections is integrated with GNSS campaigned NOAA's water level gauges. An airborne gravity-based geoid model (xGeoid20B model from NOAA's National Geodetic Survey) is utilized for the PRVI TSS grid, improving the coastal gravity signal, assisting with detecting potential errors still remaining in the retracked altimetry data. During the development, a special quality control procedure is applied to consider impacts of the steep Puerto Rico Trench bathymetry on altimetry data.

Datum TSS (VDatum convention) = vertical separation between mean sea surface and a reference equipotential surface (i.e. geoid surface) = -[MSS (mean sea surface from altimetry)/MSL (mean sea level at tide gauge) – N (geoid height from xGeoid20B)] = - MDT

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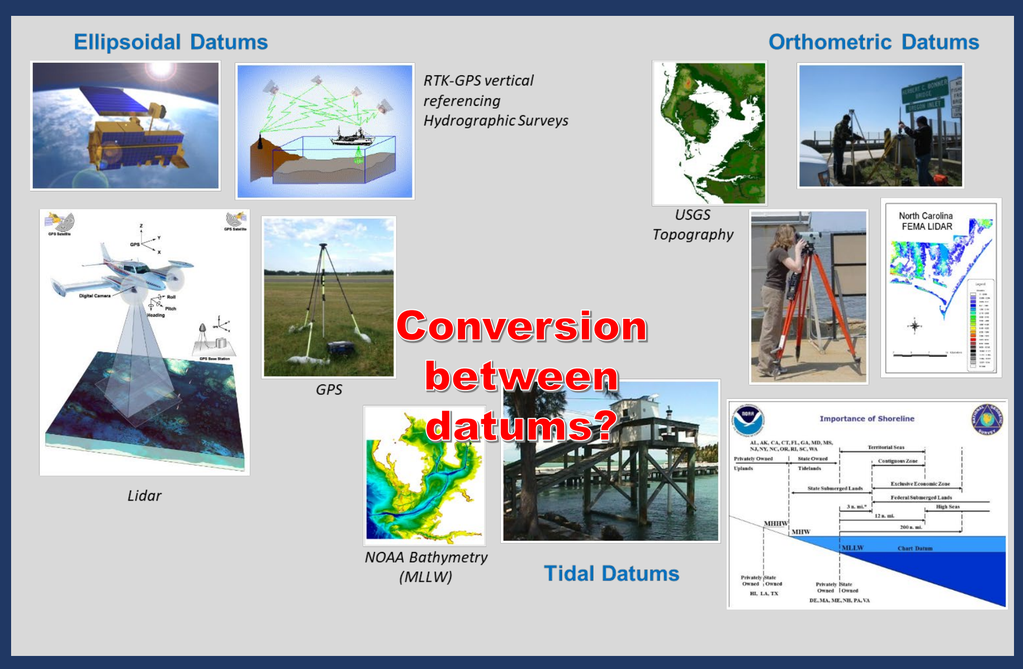
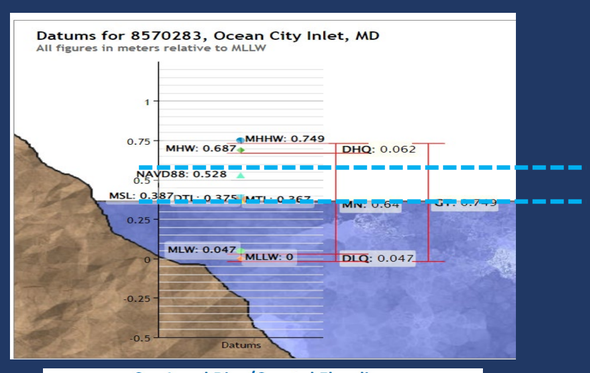
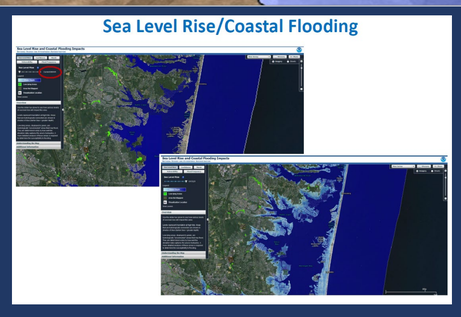
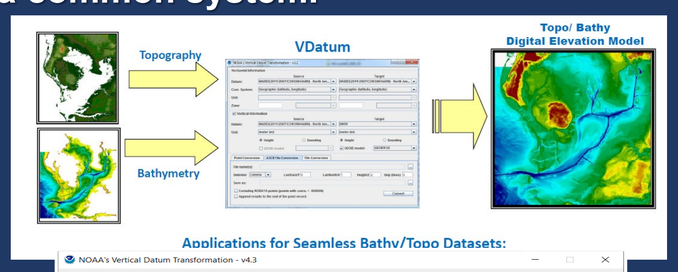
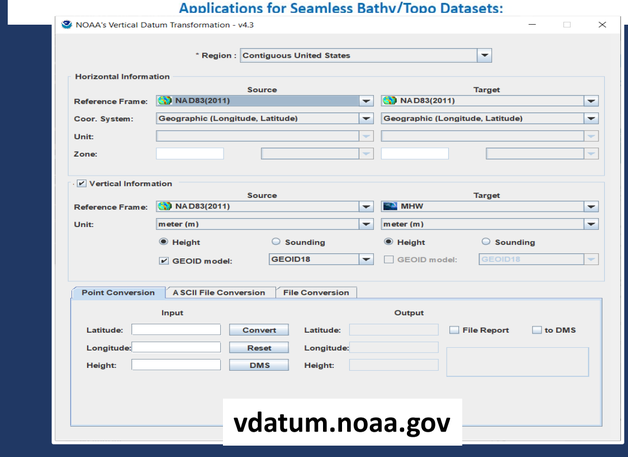




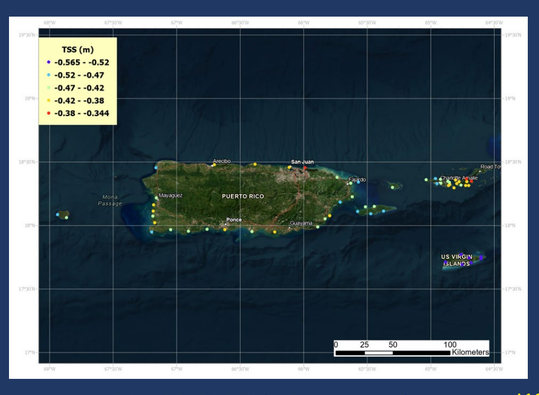






NOAA CO-OPS Tide Gauge with GNSS Campaign

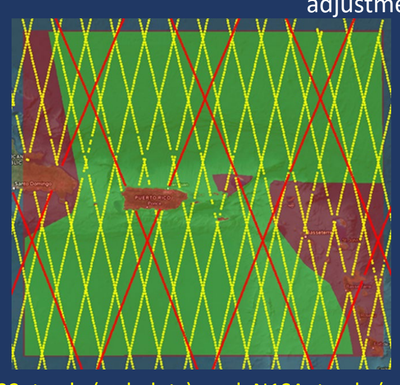
- MSL (mean sea level) is the mean of hourly heights observed over the NTDE (National Tidal Datum Epoch)
- NTDE is the official time period of tidal observations that are used for primary datum calculations.
- Dense network of water level observation associated with geodetic ties, is available for coastal area.



NOAA CO-OPS Tide Gauges used

Multi-mission Retracked Altimetry

- Reference repeat track : Jason 1,2 and 3 (approximately match to 2002-2020 NTDE)
- As tide gauge TSS, w/o dynamic atmospheric correction (DAC), is the reference to which altimetric TSS is merged, DAC correction should not be applied to altimetric TSS. This ensures the altimetric MSS becomes the 'physically' touched sea level, necessary for the use of VDatum for coastal hazard applications.
- As there are still MSS discrepancies at cross-over points, cross-over adjustment is applied to repeat & geodetic mission tracks.



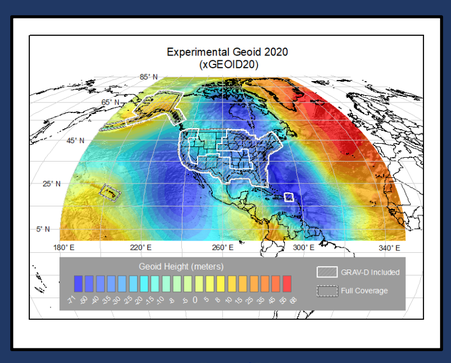
J123 track (red dots) and N1SA track (yellow dots)

Track	Mission	Cycle/Period	Data source
J123 repeat track : 2002~2019 (~18 years)	Jason-1 (J1)	001 - 259 (Jan 2002 - Jan 2009)	TUM OpenADB (1Hz)
	Jason-2 (J2)	001 - 303 (Jul 2008- Oct 2016)	
	Jason-3 (J3)	001 - 117 (Feb 2016- Apr 2019)	
N1SA repeat track : 2002-2010, 2013-2016 (~11.5 years)	Envisat (N1)	007 - 093 (Jun 2002 - Oct 2010)	
	SARAL/AltiKa (SA)	001 - 035 (Mar 2013- Jul 2016)	
J1GM (~1 year)	Jason-1 (J1GM)	500 - 537 (May 2012- Jun 2013)	
SAdp (~3 year)	SARAL/AltiKa drifting phase (SAdp)	100 - 128 (Jul 2016- Apr 2019)	
C2 (~12 years)	Cryosat-2 (C2)	003 - 154 (Jul 2010- Mar 2022)	RADS (1Hz)

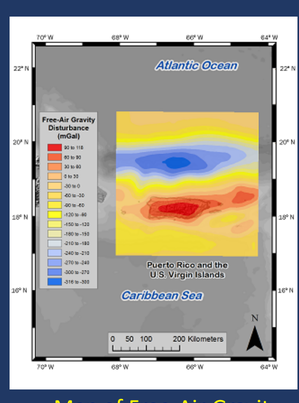
Multi-mission altimetry dataset used

Airborne Gravity based Geoid Model

- xGeoid is the NGS' experimental geoid model, annually published using satellite gravity models, terrestrial gravity and the airborne gravity from the Gravity for the Redefinition of the American Vertical Datum (GRAV-D). The project targets 1cm accuracy geoid model. The most recent version is xGeoid20B.
- Airborne gravity data covers intermediate wavelength (500km-20km), thus can roughly match the altimetric TSS resolution (say, 7-15km).

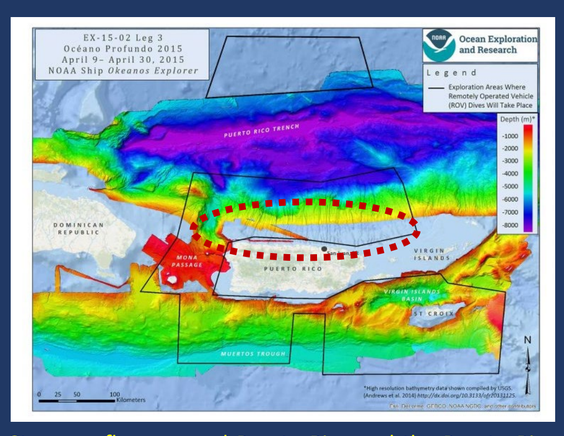


xGeoid20

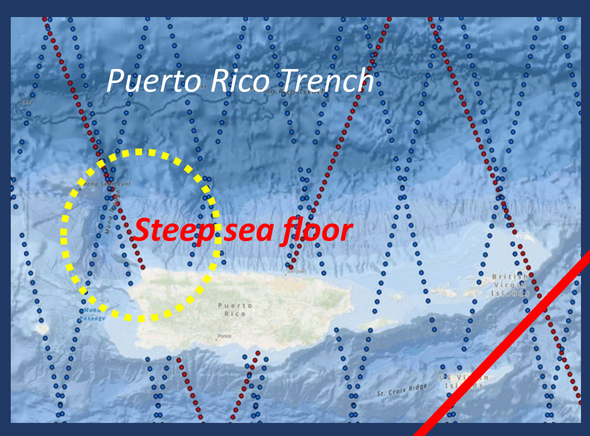


Map of Free-Air Gravity Disturbance over Puerto Rico

Quality Control for the Steep Seafloor



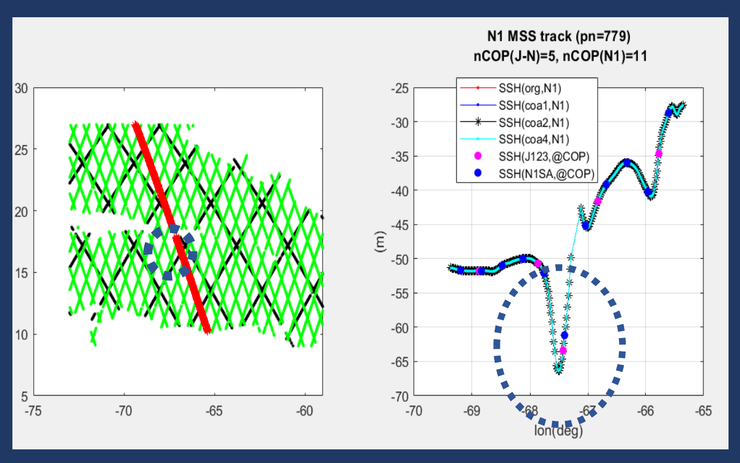
Steep seafloor around Puerto Rico and the Puerto Rico Trench (image courtesy of NOAA)



J123 track (red dots) and N1SA track (blue dots)

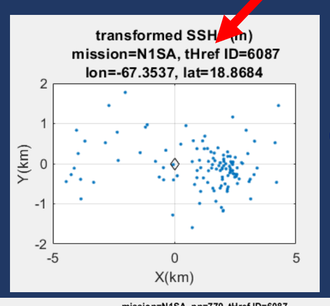
TSS = MSS (avg. SSHs in a block) – N @ reference location

Spurious TSS value pattern along a steep sea slope

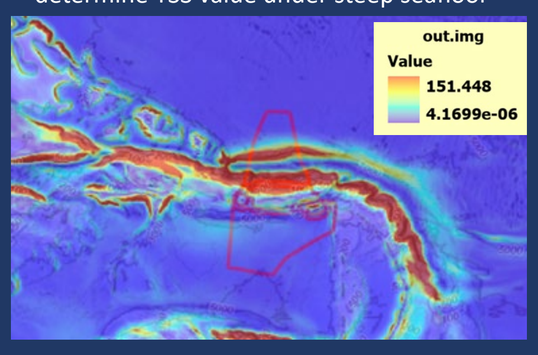


High MSS variability along the steep sea slope (i.e. marine gravity change)

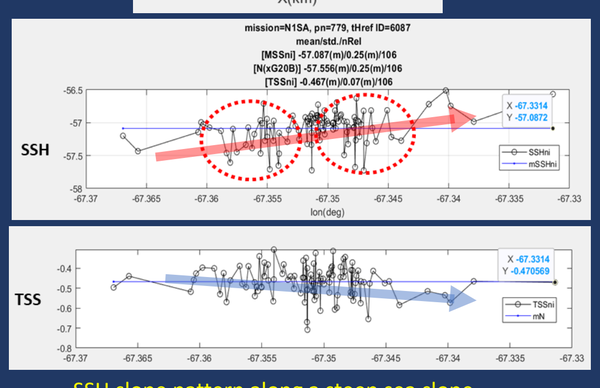
- QA/QC for TSS value pattern along the steep seafloor
- Geoid slope correction is applied (Sandwell and Smith, 2014). Correction amount over PR/VI is up to ~6.4cm for J123 and ~4.2cm for N1SA tracks
- Alternative TSS computation is used (i.e. average of individual TSS in a block)
- Intermediate scale airborne gravity signal helps determine TSS value under steep seafloor



Sample distribution of SSH observations along track



Geoid slope correction map. Unit (mm)

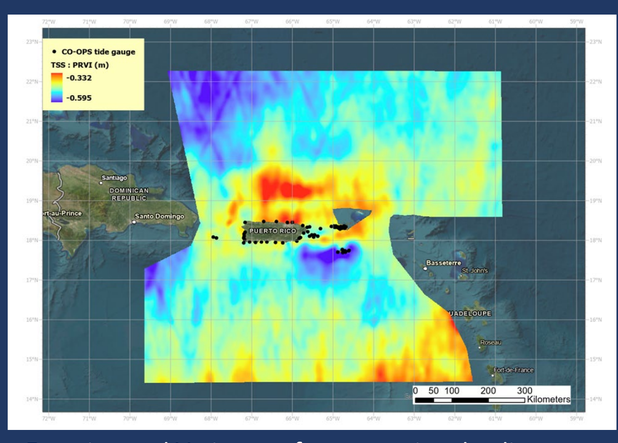


SSH slope pattern along a steep sea slope

TSS = avg. of individual TSS (N-SSH @ individual SSHs) in a block

Spurious TSS pattern is corrected

PR/USVI VDatum TSS field



- Experimental Variogram for uncertainty by distance
- Observation uncertainty from cross-over adj. statistics
- Simple objective analysis to estimate a grid TSS value
- Adjusted surface for TG-altimetry TSS bias
- QA/QC