

Accuracy analysis of Copernicus DEM and comparison to the current USGS DEM used in Landsat processing

Pecora 2022

Shannon Franks

Rajagopalan Rengarajan

Landsat Geometric Calibration Team

KBR, Contractor to the U.S. Geological Survey (USGS)

Contact: Shannon.Franks@nasa.gov

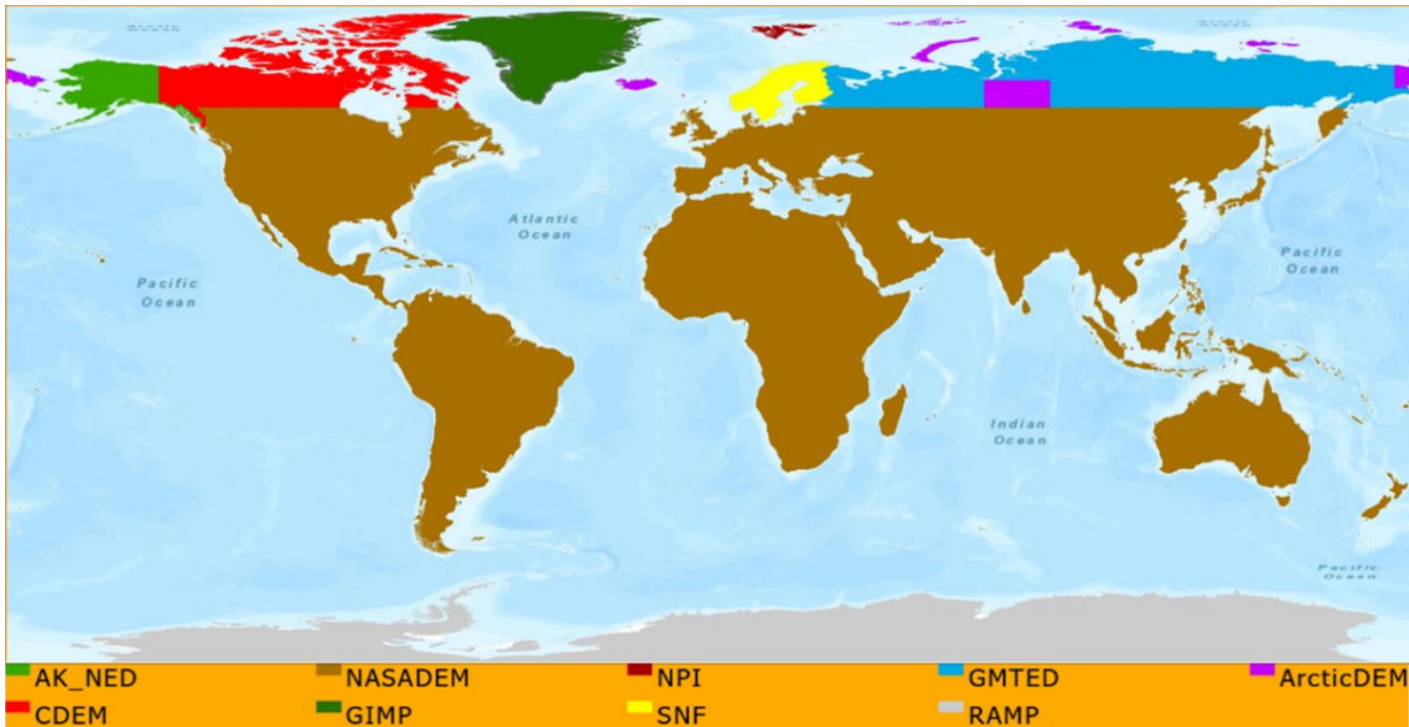
Presentation Overview

- ◆ **USGS Landsat Collection-2 DEM background**
 - ◆ Source DEM composition, Limitations
- ◆ **Copernicus DEM background**
 - ◆ Published accuracy, Highlights
- ◆ **Study Methods & Results**
 - ◆ Quantitative: accuracy assessment: National Geodetic Survey (NGS) & ICESat-2 points
 - ◆ Qualitative analysis: path to path registration via Anaglyphs
- ◆ **Conclusions**

USGS Collection-2 DEM

- ◆ **Used for Landsat Terrain Correction**
- ◆ **Comprised of many source DEMs, but mainly NASADEM**
- ◆ **3 arcsecond resolution**
- ◆ **Vertically reference to Earth Gravity Model '96 (EGM96)**
- ◆ **Time of acquisition 2000 – 2018**
- ◆ **Global Coverage**

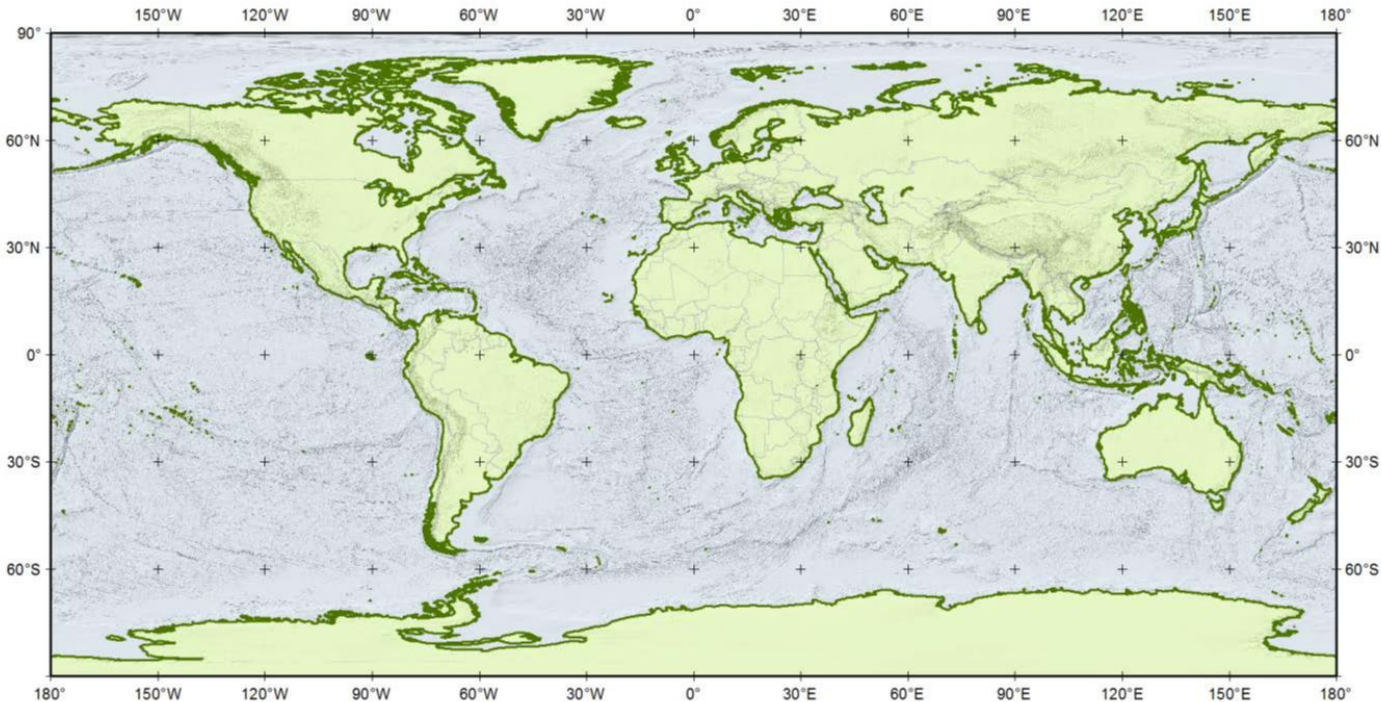
USGS Collection-2 Source DEMs



EU Copernicus DEM

- ◆ **Used for Sentinel-2 Terrain Correction**
- ◆ ***Less than 1%* of the DEM dataset is from other sources: SRTM30, ASTER**
- ◆ **1 & 3 arcsecond available globally, 0.4 arcsec in EU**
- ◆ **Vertically reference to EGM08**
- ◆ **Time of acquisition 2011 – 2015**
- ◆ **Published absolute accuracy is < 4m (LE90)**

Copernicus DEM



Absolute Accuracy Assessment

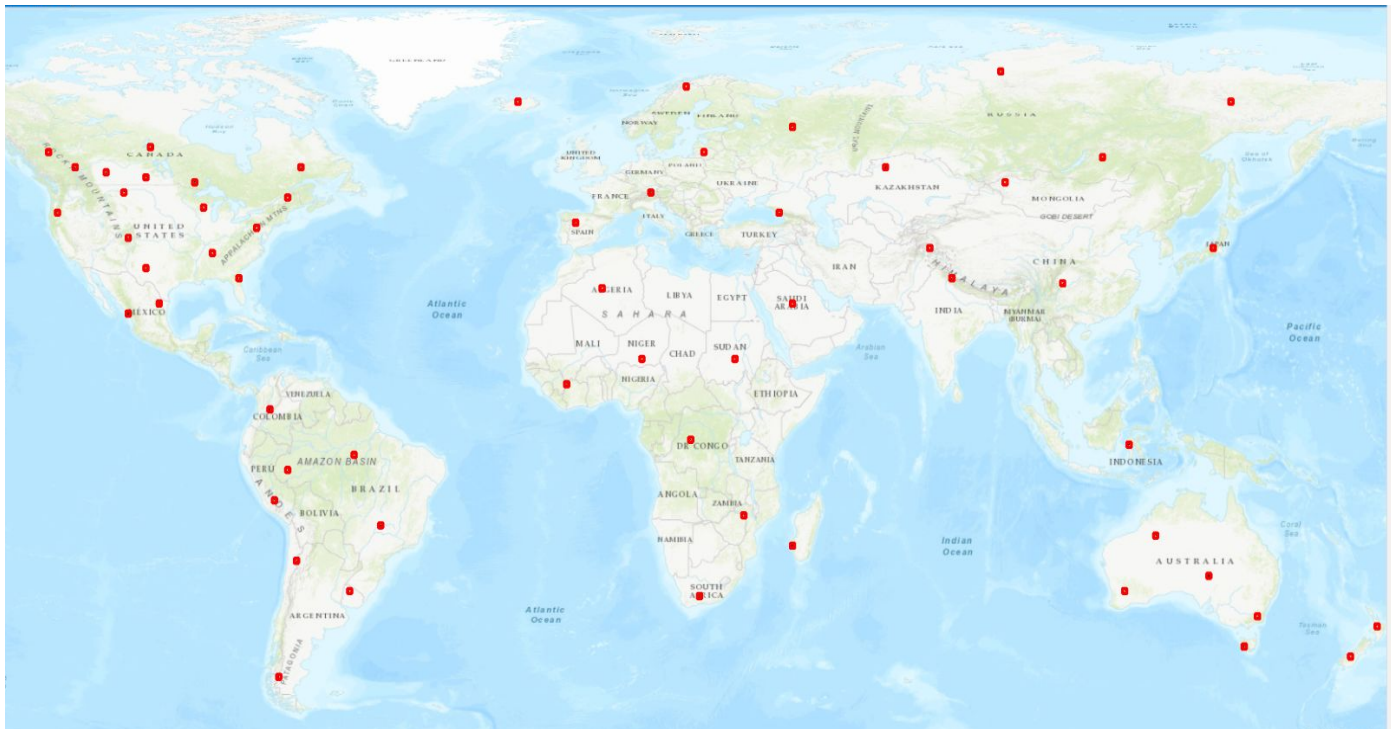
National Geodetic Survey (NGS) points

- ◆ Used in North America

ICESat-2 ATLAS points

- ◆ ATL08 product: Land & Vegetation height
- ◆ Converted from WGS84 to EGM08 via NOAA's VDatum
- ◆ Filtered data to include only reliable points
- ◆ Used as reference elevation against DEM layers
- ◆ Had ~15K ICESat-2 points per 1° tile

Distribution of study sites (n=60)



Accuracy Assessment- Continental View

	North America (18 sites)		South America (8 sites)		Europe (7 sites)		Africa (8 sites)		Asia (12 sites)		Australia (7 sites)	
	Copernicus	Collection-2	Copernicus	Collection-2	Copernicus	Collection-2	Copernicus	Collection-2	Copernicus	Collection-2	Copernicus	Collection-2
# of Points	208,094		65,657		93,262		206,364		203,210		112,576	
Range	-81 to 40	-81 to 46	-64 to 21	-117 to 20	-40 to 41	-169 to 126	-29 to 5	-21 to 21	-98 to 85	-267 to 393	-42 to 11	-42 to 54
Mean	-1.6	-0.5	-0.9	-0.9	-1.2	-0.2	-0.4	-0.4	-0.3	0.8	0.1	-0.3
STD	3.60	3.40	3.54	4.30	4.10	4.45	1.50	2.00	1.96	8.70	1.65	2.50
RMSE	3.95	3.41	3.65	4.40	4.28	4.46	1.54	2.05	1.98	8.72	1.65	2.51

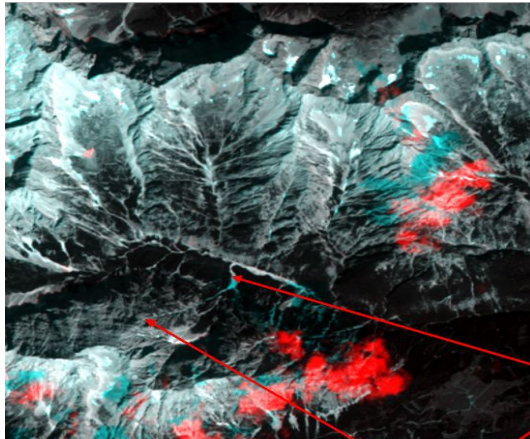
- The superior results of the Collection-2 DEM in N.A. is due to CDEM's performance
- NASADEM, by itself, is comparable to Copernicus in N.A. and slightly worse in other parts of the world
- The largest improvement of the Copernicus DEM is in Asia, due to NASADEM struggling in high-elevation Himalayas and Northern Russia where GMTED was used as the C2 source.
- Globally, the improvement with using the Copernicus DEM will be around 2 meters.

Global (60 sites)	
Copernicus	Collection-2
n = 889,113	
-98 to 85	-267 to 393
-0.7	-0.2
2.80	5.00
2.90	5.04

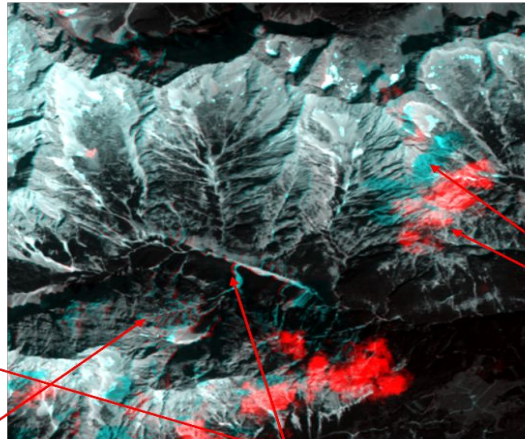
Qualitative Assessment- Anaglyphs

Used both DEMs to terrain correct overlapping Landsat imagery to analyze if there are path-to-path misalignments due to the differing view angles.

Austrian 3-arcsec



WorldDEM 3-arcsec



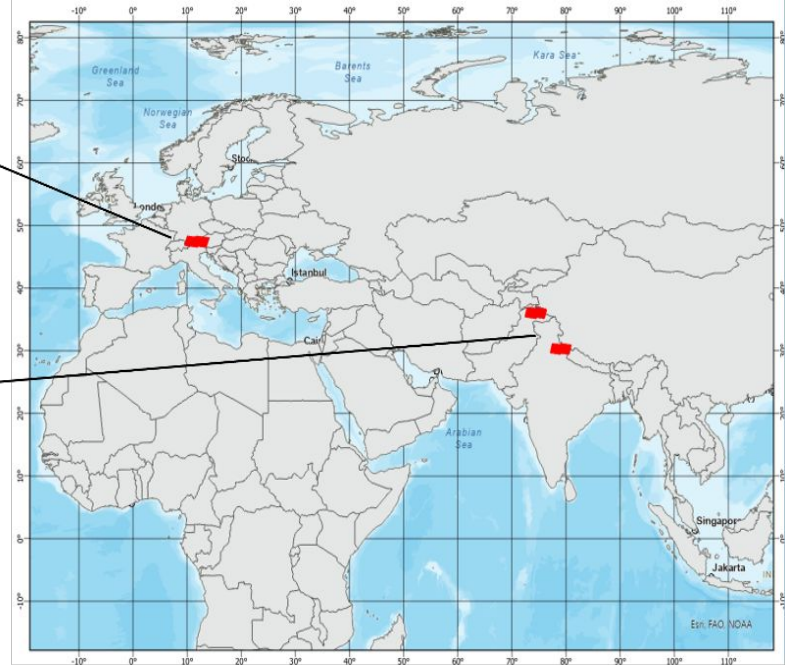
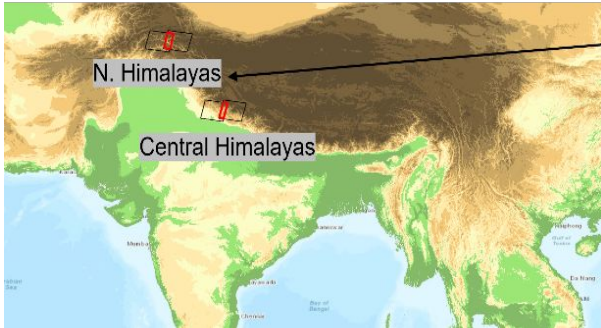
clouds and shadows in one of the images

WorldDEM has major problem here

WorldDEM is worse in the valley

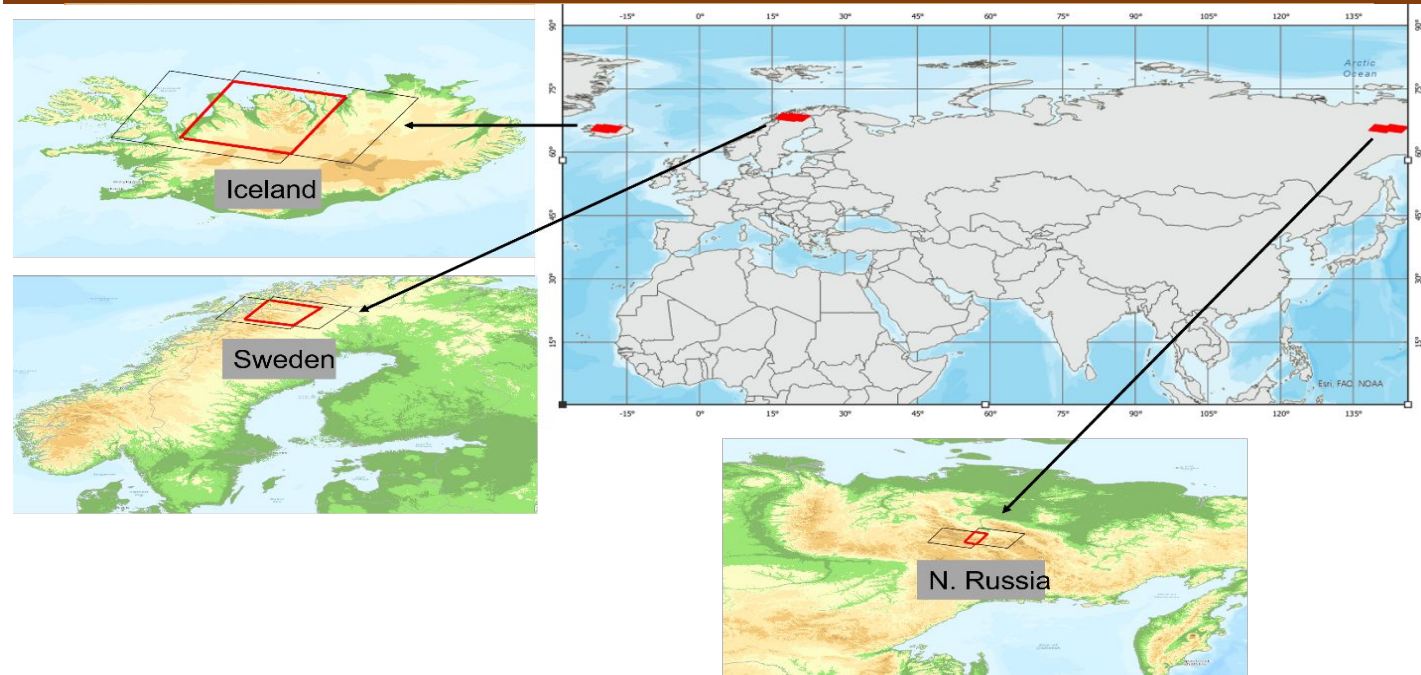
Qualitative Assessment- Anaglyphs

Below 60-degrees we focused on regions with high relief



Qualitative Assessment- Anaglyphs

Above 60-degrees we focused on the differing Collection-2 source DEMs



Anaglyph Results

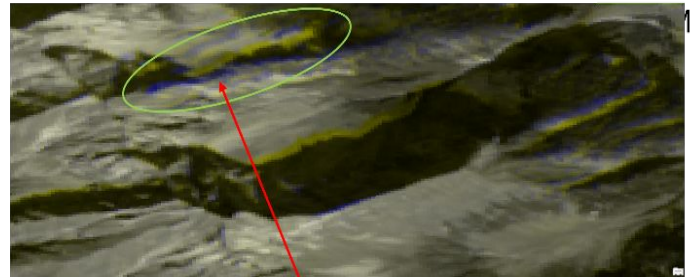
Images processed with Collection-2 DEM



Images processed using the Collection-2 DEM has problem here



Images processed with Copernicus DEM



Images processed using the Copernicus DEM has problem here



Conclusions

- ◆ **For most of the world, the DEM currently being used by the USGS (Collection-2) is comparable to the Copernicus DEM.**
- ◆ **Two exceptions are:**
 - ◆ In the Himalayas, where there are sharp and steep elevation gradients
 - ◆ In Northern Russia, where the Collection-2 DEM used the GMTED DEM dataset.
- ◆ **The increased resolution of the Copernicus DEM and the seamless global coverage are the main improvements and contribute to the justification towards using it in future Landsat processing.**

Thank You

Collection-2 source DEM view- was any of the C2 DEMs better?

	NASADEM (46 sites)		CDEM (8 sites)		SNF (1 site)		ArcticDEM (2 sites)		GMTED (3 sites)	
	Copernicus	Collection-2	Copernicus	Collection-2	Copernicus	Collection-2	Copernicus	Collection-2	Copernicus	Collection-2
# of Points	n = 672,299		n = 92,631		n = 18,632		n = 51,548		n = 54,003	
Range	-98 to 85	-117 to 393	-81 to 40	-81 to 46	-8 to 14	-28 to 22	-16 to 17	-169 to 126	-29 to 14	-267 to 120
Mean	-0.6	-0.5	-1.5	0.0	0.5	-0.5	-0.2	0.4	-1.7	3.7
STD	2.64	3.00	3.25	2.90	1.18	3.40	2.06	4.00	4.10	15.90
RMSE	2.70	3.07	3.58	2.90	1.26	3.46	2.07	4.02	4.46	16.32

Accuracy Assessment- using NGS points

Backup Slide

	CONUS		Canada		Mexico		North America	
	Copernicus	Collection-2	Copernicus	Collection-2	Copernicus	Collection-2	Copernicus	Collection-2
# of Points	n = 30,417		n = 570		n = 197		n = 31,185	
Range	-30 to 59	-25 to 51	-12 to 11	-9 to 18	-18 to 7	-13 to 6	-30 to 59	-25 to 51
Mean	0.30	0.00	-0.20	1.22	0.00	0.03	-0.30	0.00
STD	1.90	2.60	2.07	2.40	1.75	2.40	1.90	2.66
RMSE	1.90	2.63	2.07	2.68	1.75	2.41	1.90	2.66

Copernicus Fill Data comparison

- where COP DEM used fill, could they have done better?

	North America		South America		Europe		Africa		Asia		Australia	
	Copernicus	Collection-2	Copernicus	Collection-2	Copernicus	Collection-2	Copernicus	Collection-2	Copernicus	Collection-2	Copernicus	Collection-2
# of Points	n = 858		n = 125		n = 511		n = 21		n = 529		n = 137	
Range	-53 to 17	-43 to 29	-44 to 4	-52 to 12	-32 to 41	-50 to 62	-22 to 3	-17 to 6	-98 to 85	-116 to 393	-42 to 4	-42 to 6
Mean	-9.9	-8.4	-8.1	-10.2	-7.9	-5.4	-6.5	-5.9	-0.5	-0.8	-10.4	-4.7
STD	7.70	7.30	10.00	10.90	9.70	8.60	7.20	6.20	13.20	27.90	13.50	7.10
RMSE	12.49	11.16	12.88	14.87	12.49	10.16	9.59	8.44	13.20	27.89	16.97	8.46