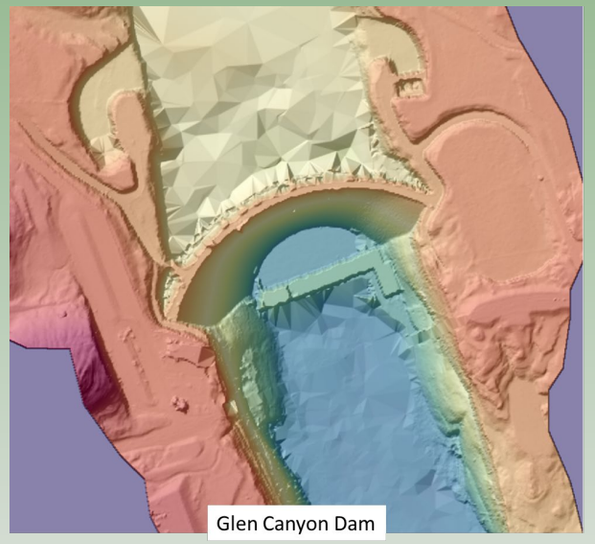
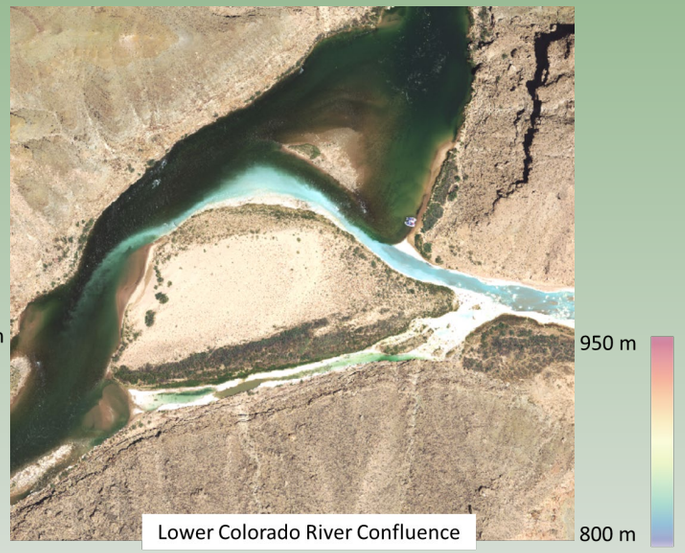
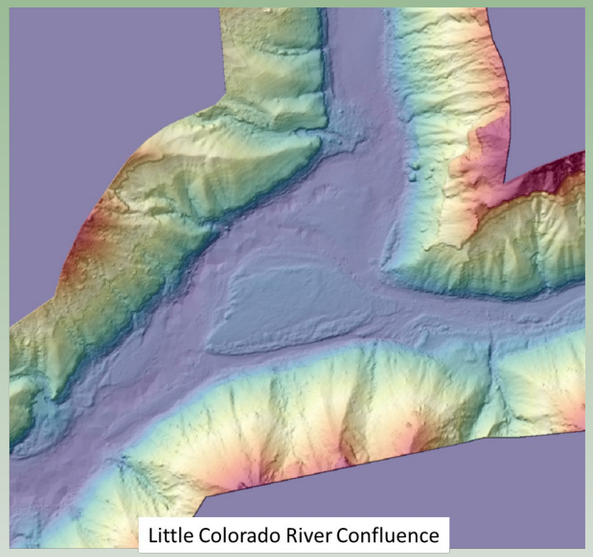
Overflight Remote Sensing in Support of Long-Term Monitoring and LTEMP







Glen Canyon Dam Adaptive Management Program Annual Reporting Meeting
January 23-24, 2024, Phoenix, AZ

Joel B. Sankey, US Geological Survey (USGS), Southwest Biological Science Center (SBSC),
Grand Canyon Monitoring and Research Center (GCMRC)
Nathaniel Bransky, Northern Arizona University (NAU)
Thomas Gushue, USGS, SBSC, GCMRC
Keith Kohl, USGS, SBSC, GCMRC
Lori Pigue, USGS, Astrogeology Science Center (ASC)

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Project Goals and Objectives

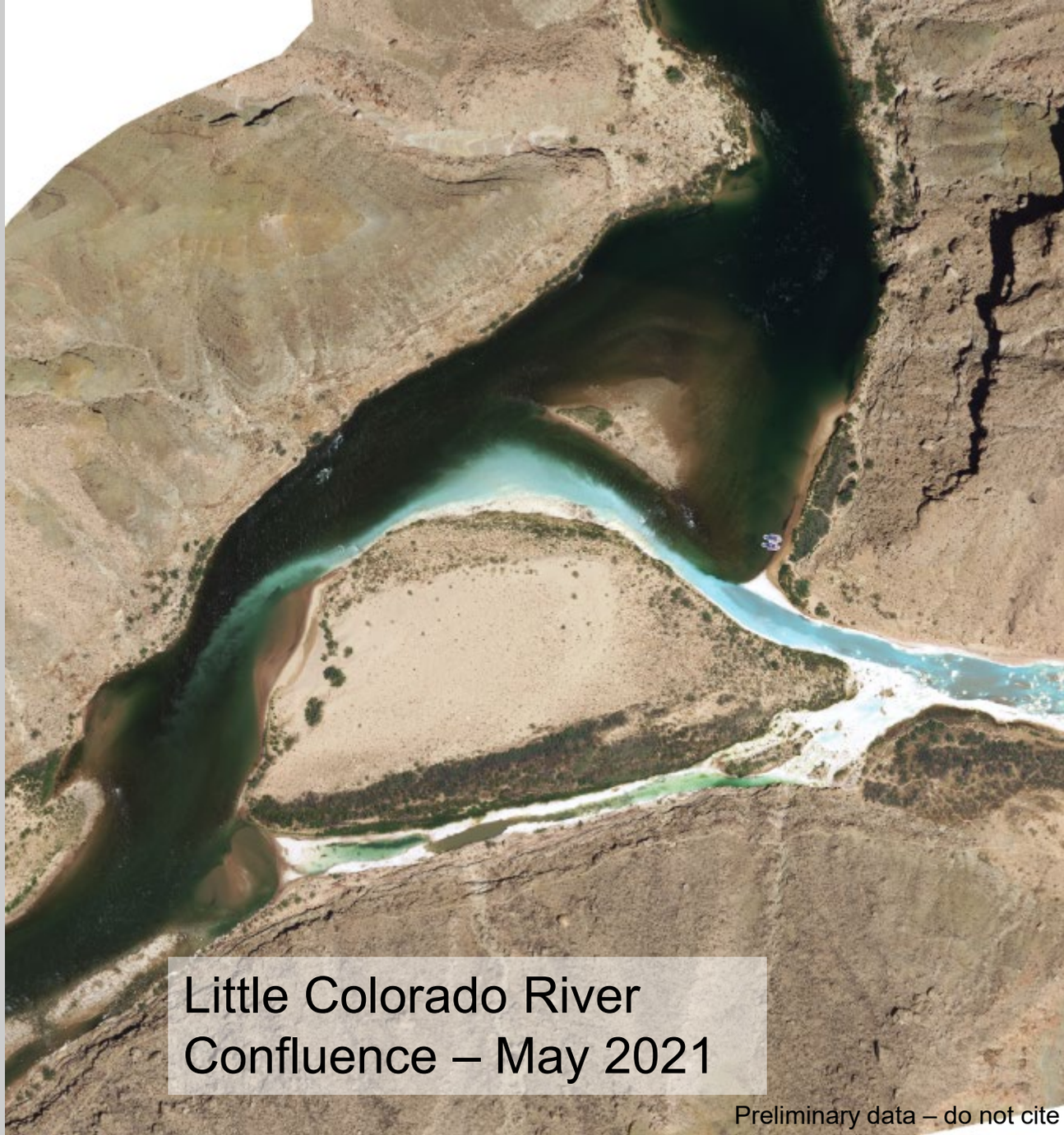
GCMRC Triennial Workplan (TWP)
Project L FY2021/2022/2023/2024
Budget $892k/$284k/$316k/$352k

Imagery and derivative data products from overflight remote sensing are used either directly or indirectly by every science project proposed in the TWP to address every resource goal of the LTEMP

Science Questions:

• How has landcover changed in the Colorado River Ecosystem (CRe) at decadal timescales?

• How are observed landcover changes related to dam operations, other land use and management activities, as well as climate and other environmental factors in the ecosystem?



Airborne Remote Sensing in Grand Canyon

The high-resolution image collection from GCDAMP's May 2021 overflight is the most recent in a rich archive of aerial imagery that is used to track changes of the Colorado River in the Grand Canyon.

History of aerial remote sensing in Grand Canyon:

- Earliest air photos are black and white prints acquired from an airplane in 1935.
- First set of air photos acquired after Glen Canyon Dam was completed are black and white prints from May 1965
- First color and color-infrared air photos were acquired during flights in the 1980s
- First digital multispectral images were acquired in the late-1990s
- First acquisition similar to the May 2021 overflight (high spatial resolution digital multispectral imagery and digital topography) occurred in May 2002, and then again in 2004, 2005, 2009, 2013, 2021

https://www.usgs.gov/centers/southwest-biological-science-center/science/airborne-remote-sensing-grand-canyon

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May 2021 Overflight Status

Fiscal Year	Quarter(s)	Activities
2021	1st	· Write Task Order and negotiate contract with GPSC (USGS Geospatial Products and Services Contracts) and contractor for overflight mission consisting of imagery and digital topographic data acquisition
	2nd	· Contract awarded to Fugro Earth Data Inc. · Coordinate logistics for the overflight mission with GCDAMP agencies and stakeholders Plan GCMRC logistics, including the rim- and river-level operations to be conducted by GCMRC in coordination with the contractor
	3rd	· Overflight mission · Rim-level GPS base station operations · River-level accuracy assessment and ground-truthing operations
	4th	· Monitor image processing performed by Fugro (contractor)
2022	1st	· Data delivered to GCMRC · QA/QC performed by GCMRC in coordination with vendor
	2nd	· Final modifications to mosaic performed
	3rd & 4th	· Begin publication process for finalized mosaic
2023	All	· Image mosaic published · Landcover classification maps produced by GCMRC remote sensing staff

- Sankey, J.B., Bransky, N., Pigue, L., and Kohl, K., *In Press*, Four band image mosaic of the Colorado River corridor downstream of Glen Canyon Dam in Arizona derived from the May 2021 Airborne image acquisition: U.S. Geological Survey data release, to be published at https://doi.org/10.5066/P9BBGN6G.
- Sankey, J.B., Kohl, K., Gushue, T., Bransky, N., Bedford, A., Durning, L., Davis, P.A., *In Prep.,* DSMs for Colorado River Corridor in Grand Canyon National Park and Glen Canyon National Recreation Area: 2002, 2009, 2013 and 2021 and DEM for 2021: U.S. Geological Survey data release

Preliminary results, please don't cite

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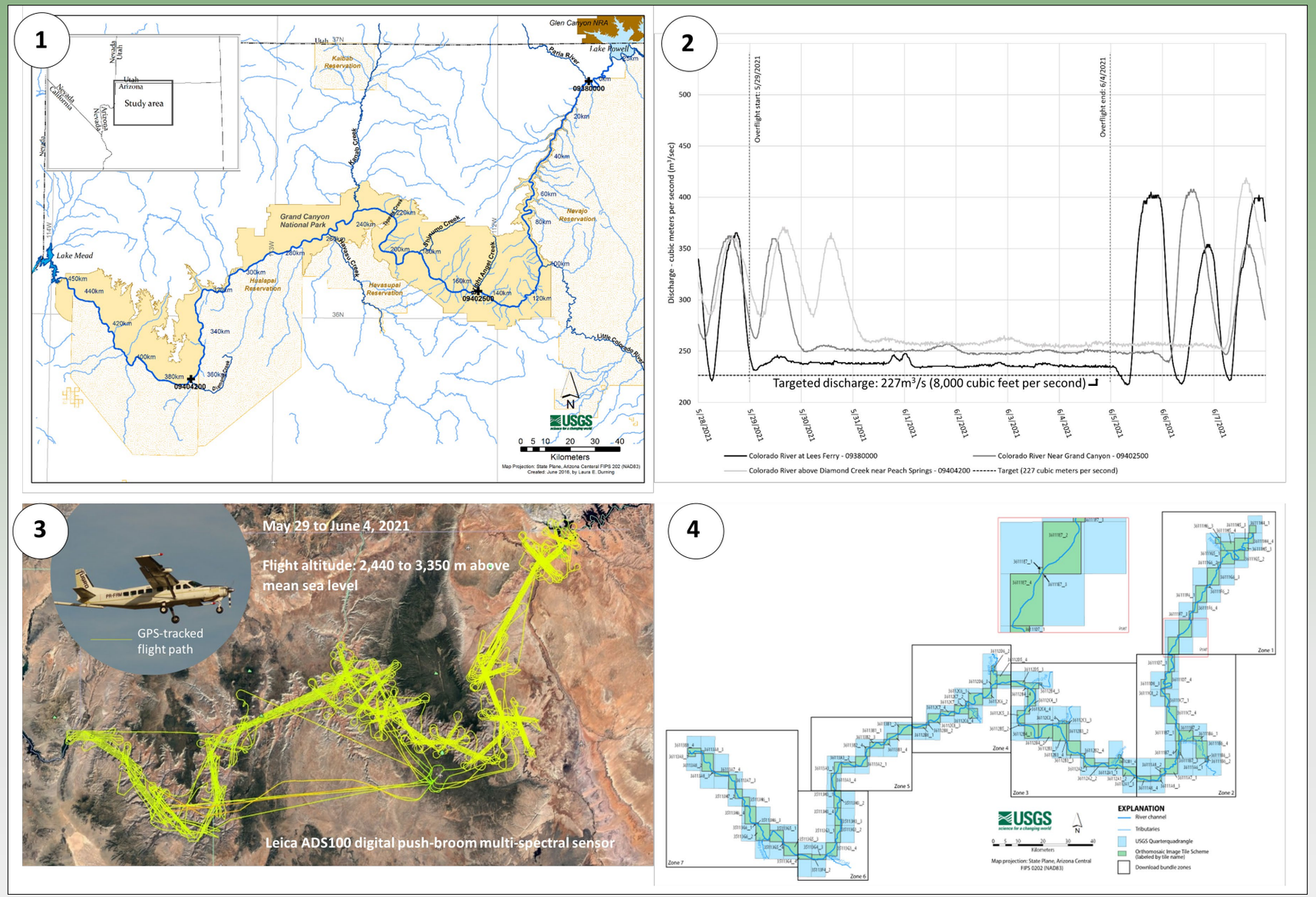
2021 Overflight Orthomosaic

Data Collection by Fugro, Inc. under contract with the USGS Grand Canyon Monitoring and Research Center

1. Collected from just upstream of Glen Canyon Dam (in Lake Powell) near Page, Arizona, downstream to Lake Mead's Pearce Ferry, Arizona, for a total length of 475 kilometers (km) at a width of about 500 meters (m) centered on the mainstem of the Colorado River and seven primary tributaries
2. Targeted river discharge of 227 m^3/s (8,000 cubic feet per second)
3. For any given section of the river corridor, five or six overlapping linear flightlines were acquired, allowing for the greatest probability of error-free and low-shadow imagery
4. Initial image orthomosaic of overlapping flightlines produced by contractor (Fugro)

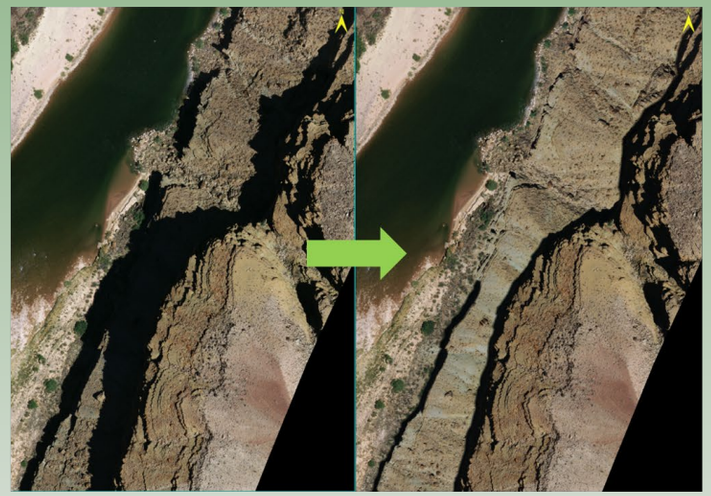


Preliminary results, please don't cite

2021 Overflight Orthomosaic

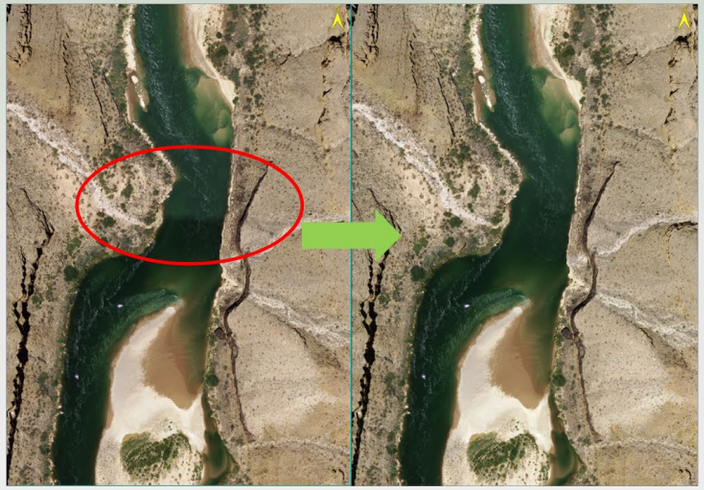
USGS Edits to Initial Mosaic

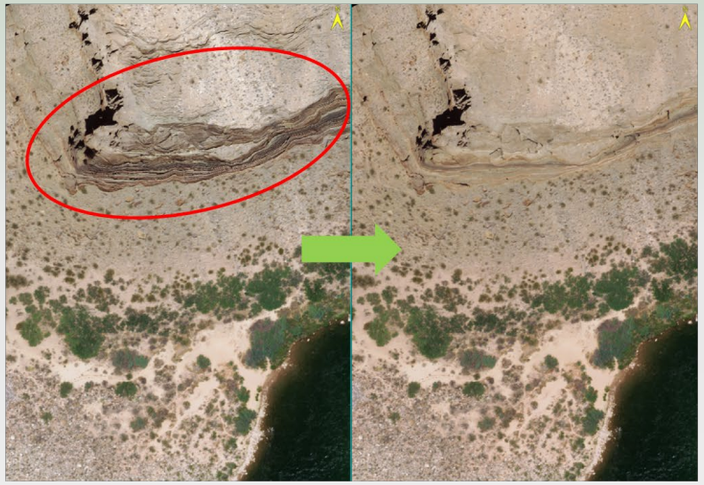
✓ Reducing shadows



✓ Fixing vegetation “smear”

✓ Smoothing cutlines





✓ Removing geologic “ripple” effect

Preliminary results, please don’t cite

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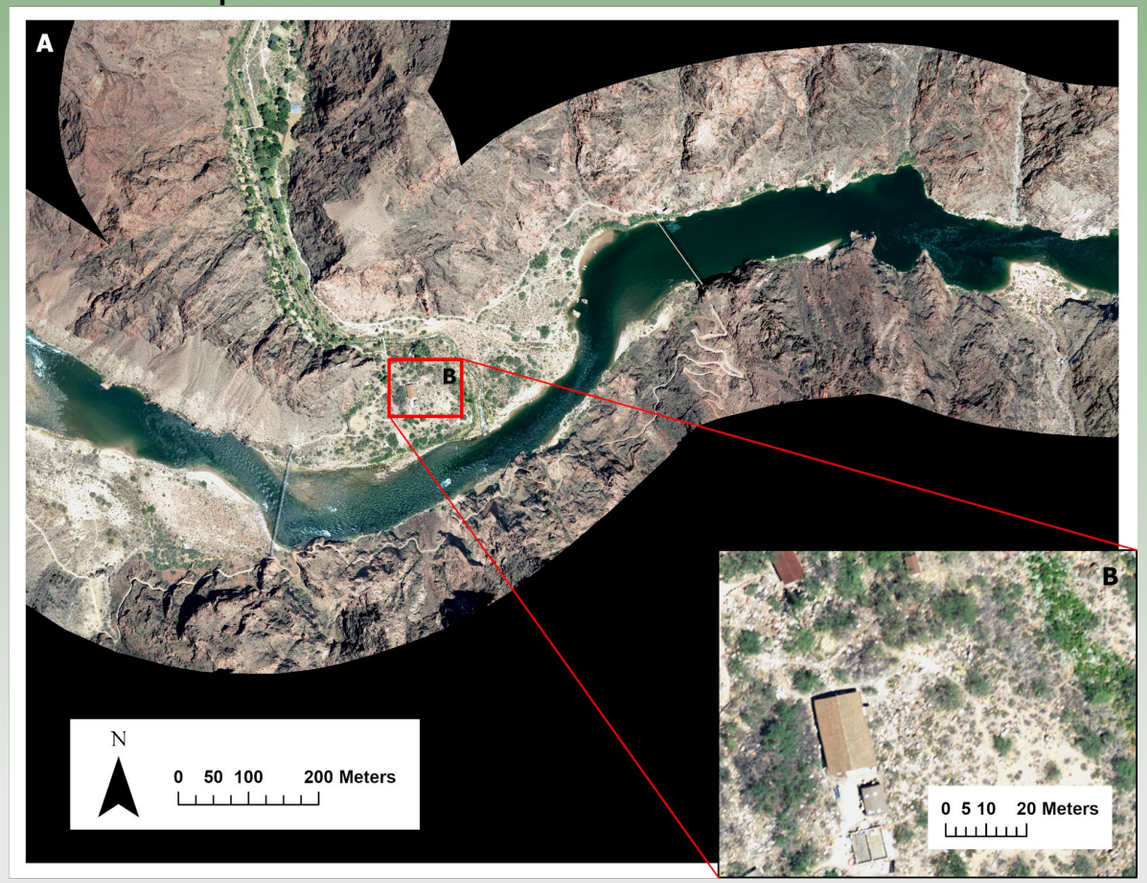
2021 Overflight Orthomosaic

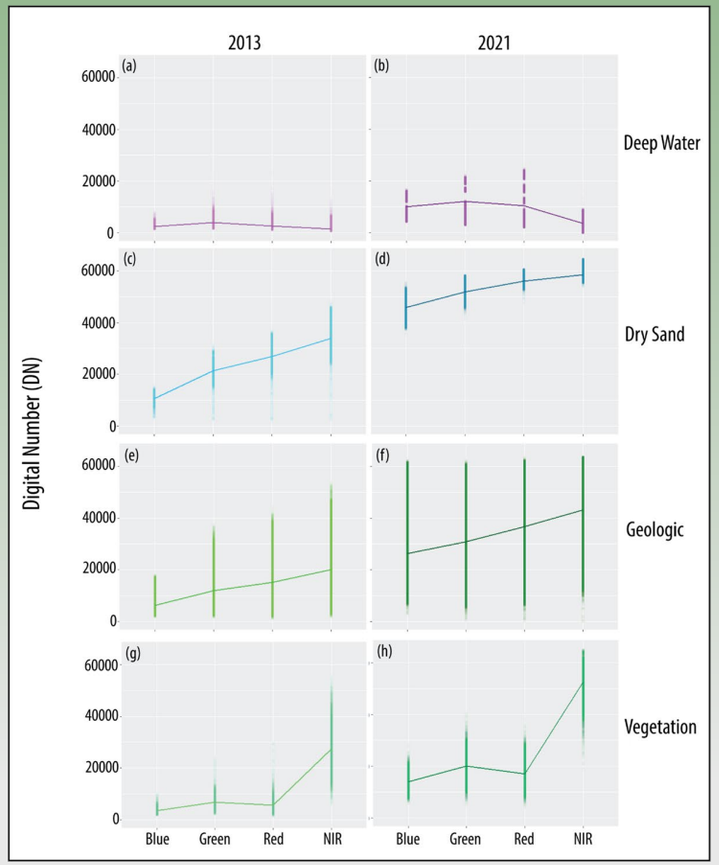
Final Mosaic Specifications



A. Imagery over Phantom Ranch, Grand Canyon National Park from final 2021 overflight mosaic
B. Zoomed view of buildings and vegetation from final 2021 overflight mosaic

- 20 cm spatial resolution
- 4 bands (Red, Green, Blue, Near-Infrared)
- Seamless mosaic checked by GCMRC scientists for smear, shadow extent, and water clarity

Havasu Creek displayed in false color composite: red is near-infrared



Data range of 2021 imagery is greater than previous image acquisitions

Preliminary results, please don't cite

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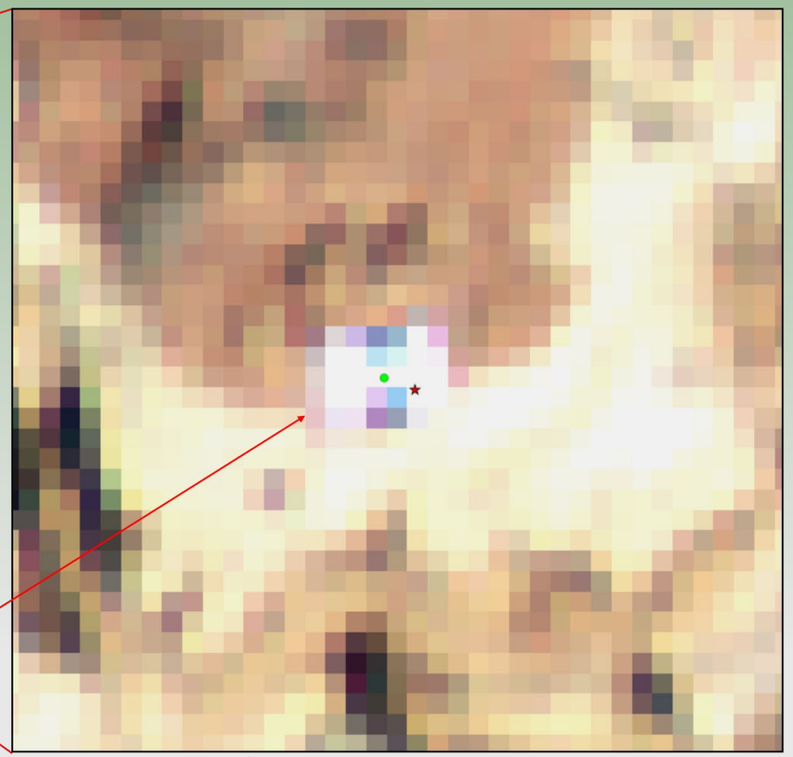
2021 Overflight Orthomosaic

Horizontal Accuracy Assessment

Calculated by finding the error between the Grand Canyon Monitoring and Research Center network of ground control points and the same points identified from target panels in the image

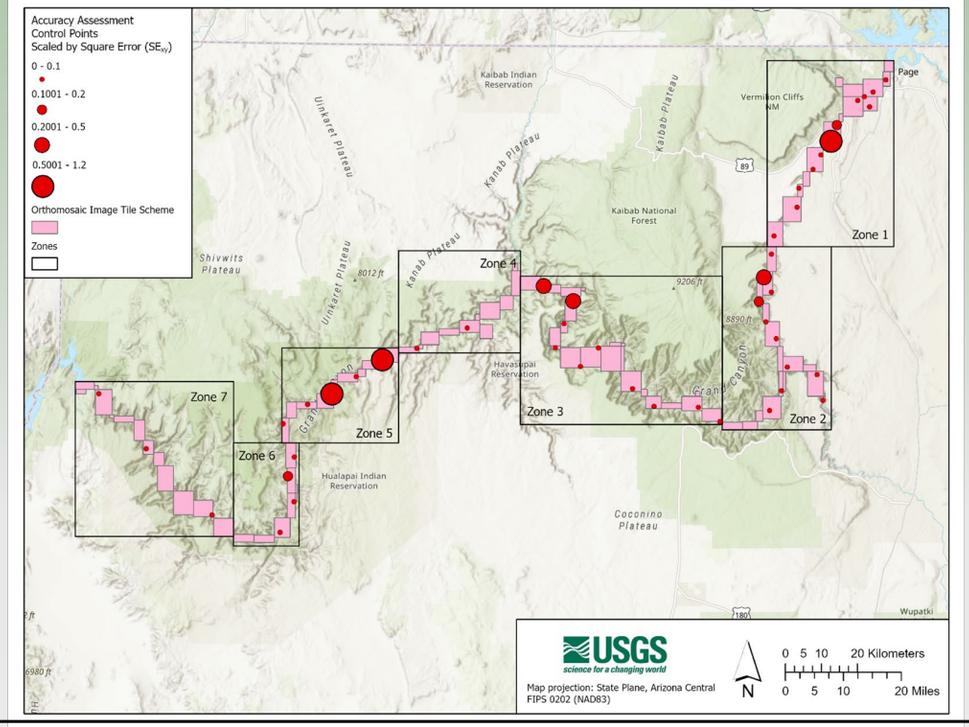


Error calculated at the pictured panel:
0.304 easting (x)
-0.111 northing (y)

Surveyed Ground Control Point

Target center identified in image

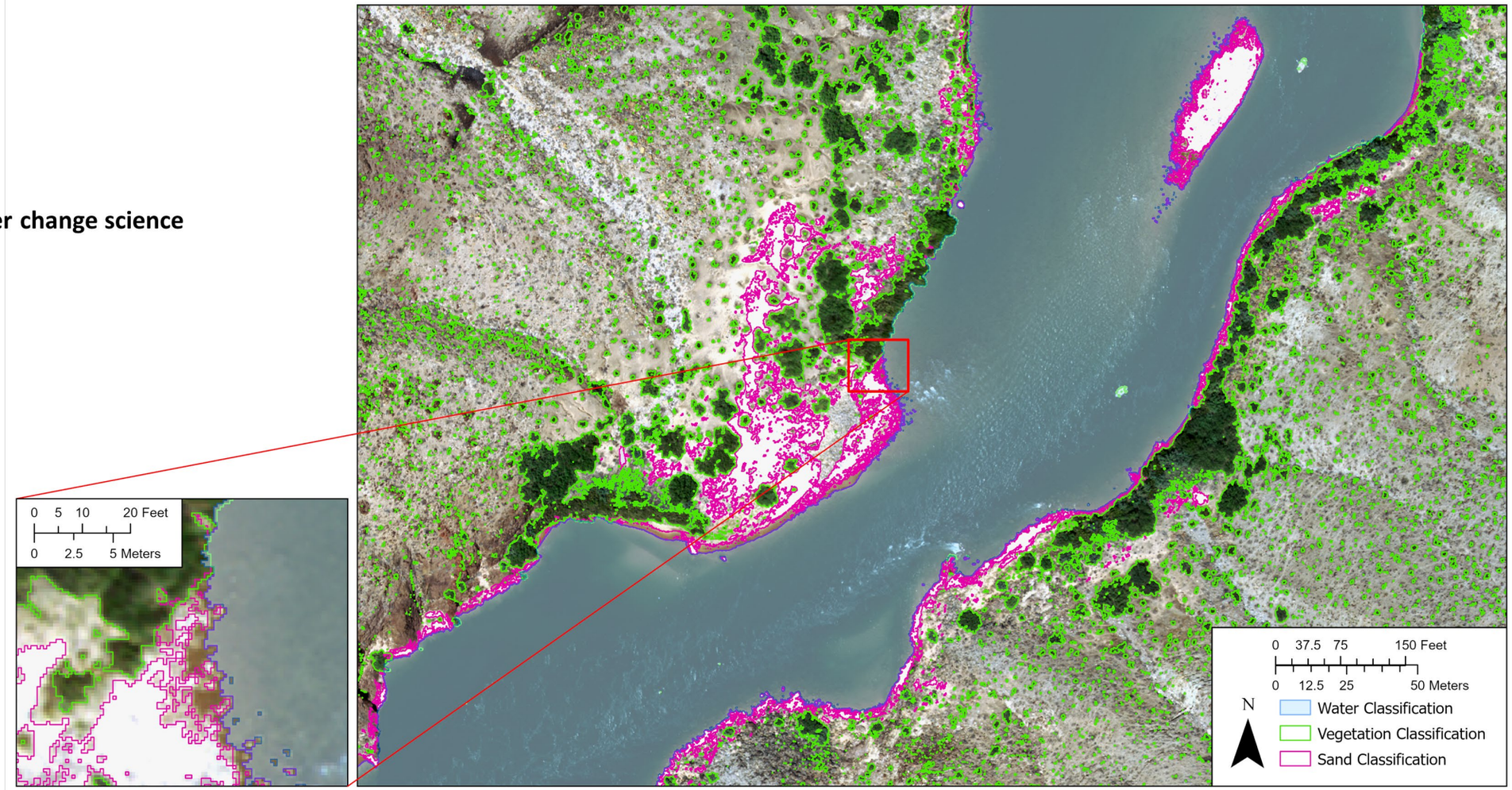
	Horizontal accuracy at 95% confidence		
Ground control point sample	Easting (X)	Northing (Y)	Combined (XY)
n = 47 not provided to, or used by, Fugro for mosaic development	0.408	0.416	0.514
n = 74 coincident between 2021 and 2013 image-data acquisitions (Durning and Others, 2016a, b)	0.609	0.583	0.744



Preliminary results, please don't cite

2021 Overflight Orthomosaic

Landcover mapping and landcover change science



Preliminary results, please don't cite

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Overflight Digital Topographic Data

Digital Surface Model (DSM) and Digital Elevation Model (DEM) Processing by Contractor

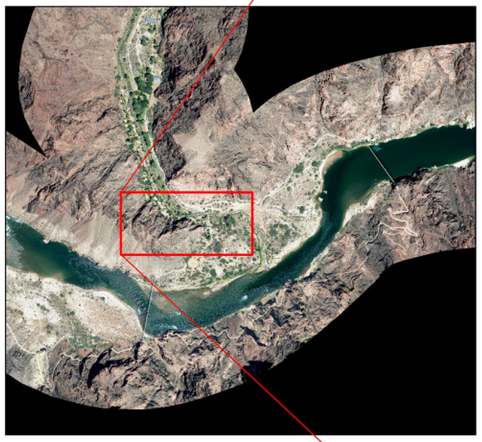
- Stereoscopic imagery from various view angles was autocorrelated to create a digital surface model (DSM)
- DSMs provide elevation data on open ground (e.g. bare soil, rocks) and on aboveground terrain features including buildings, trees, and vegetation that cover otherwise open ground
- 2021 DEM generated by removing the aboveground features from the DSM by filtering process

Preliminary results, please don't cite

Overflight Digital Topographic Data

DSM and DEM Specifications

- 1 m spatial resolution
- Each pixel represents the elevation of the surface at that point referenced to Ellipsoid



Hillshade from 2021 DSM with transparent 2021 imagery over Phantom Ranch showing topography, vegetation, and buildings near Bright Angel Creek.

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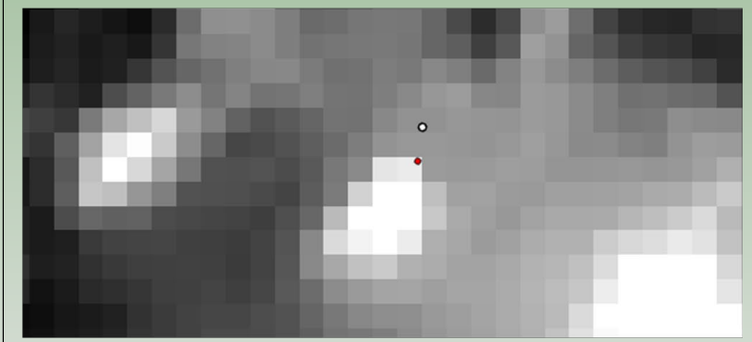
Overflight Digital Topographic Data

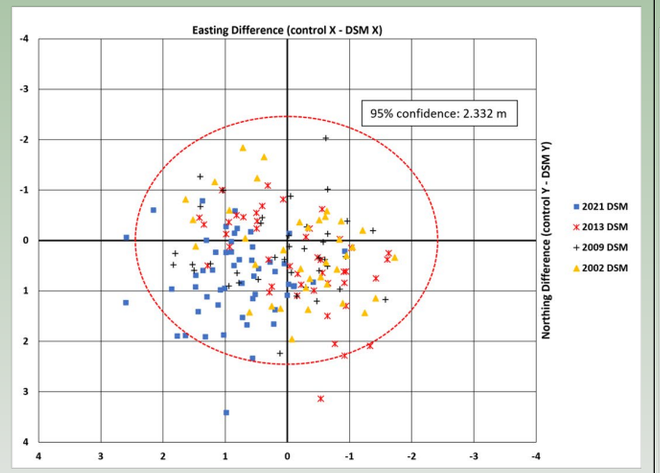
Vertical and Horizontal Accuracy Assessment

Vertical Accuracy calculated by finding the error between the Grand Canyon Monitoring and Research Center network of ground control point elevation values and the corresponding pixel elevation in the DSM

Horizontal Accuracy calculated by finding the error between the Grand Canyon Monitoring and Research Center network of surveyed “Hard Points” (e.g. corners of large, angular rock outcrops) and the same points identified in the DSM

Topographic Dataset	Vertical accuracy at 95% confidence from N=926 control points
2002 DSM	1.5066
2009 DSM	1.3506
2013 DSM	1.3787
2021 DSM	1.3785
2021 DEM	2.9186

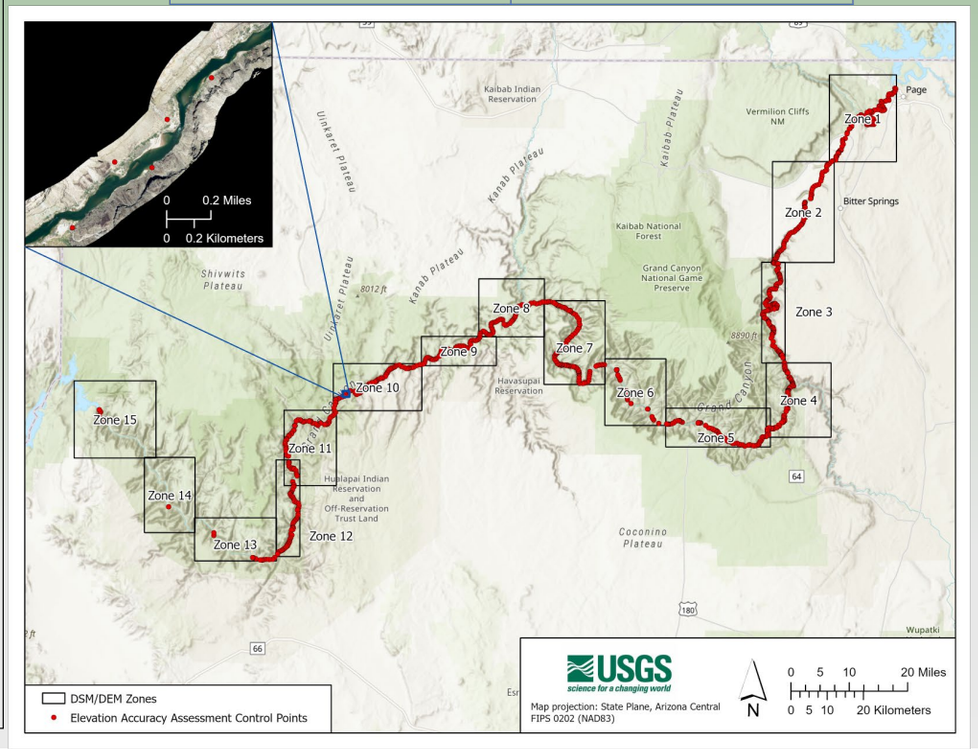




Surveyed Hard Point feature

Hard Point feature identified in DSM

Horizontal error in 2021 DSM calculated at the hard point pictured above: 0.195 easting (x), 1.376 northing (y)



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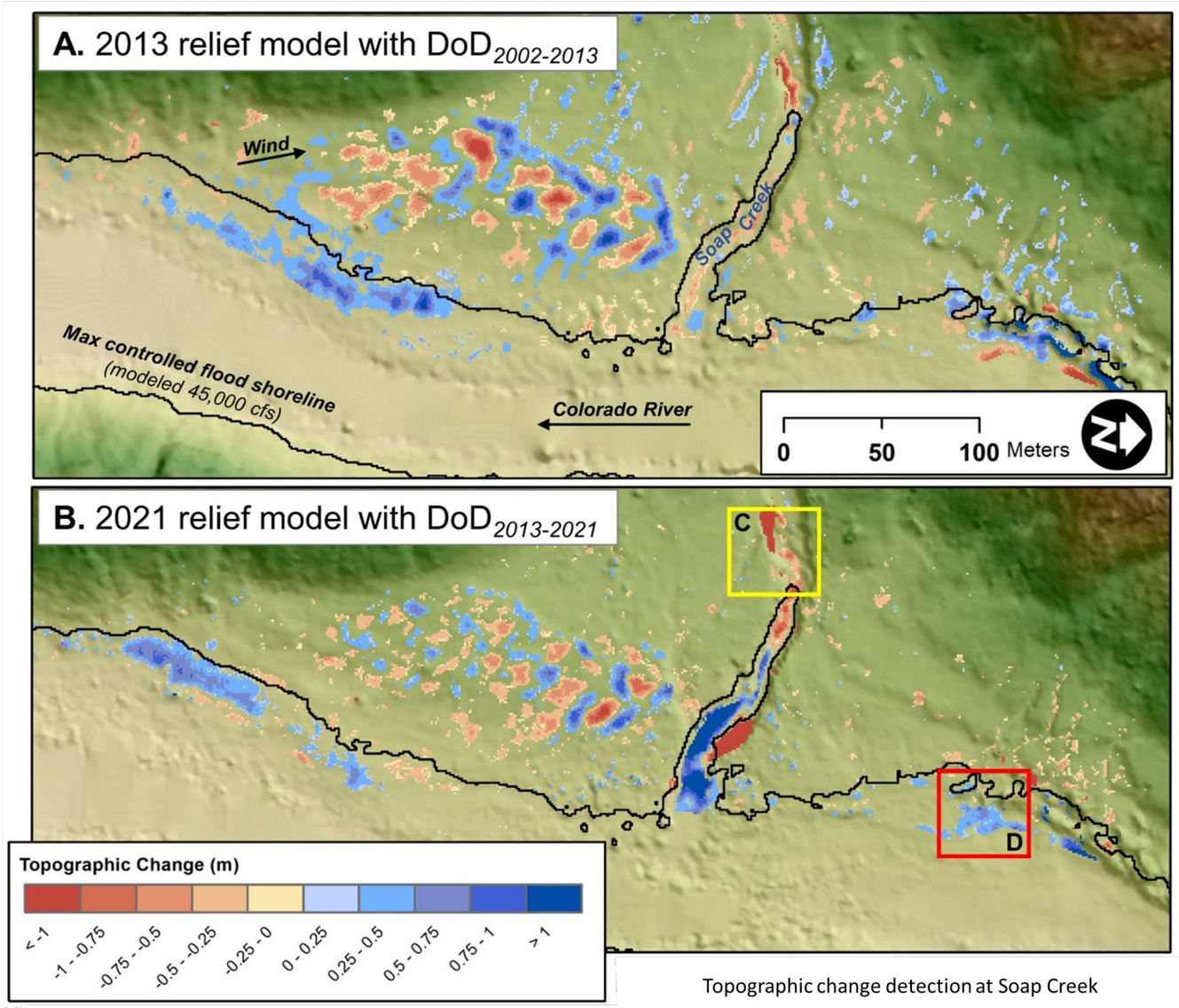
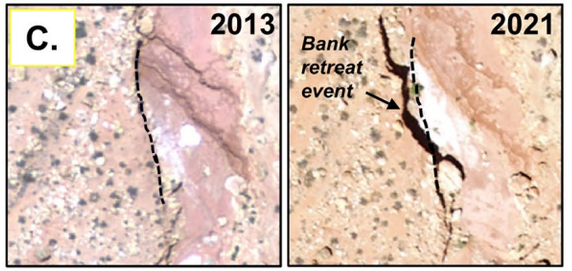
Overflight Digital Topographic Data



Topographic change detection at Soap Creek

Topographic change detection science

- **Differencing two DSMs generates a Digital Surface Model of Difference (DoD) showing topographic changes that occurred during the inter-DSM time period**
  - **$DSM_{later} - DSM_{earlier} = DoD_{later - earlier}$**

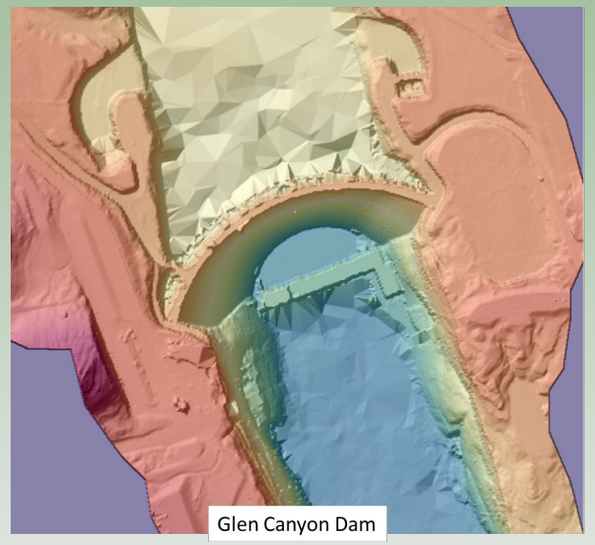


Preliminary results, please don't cite

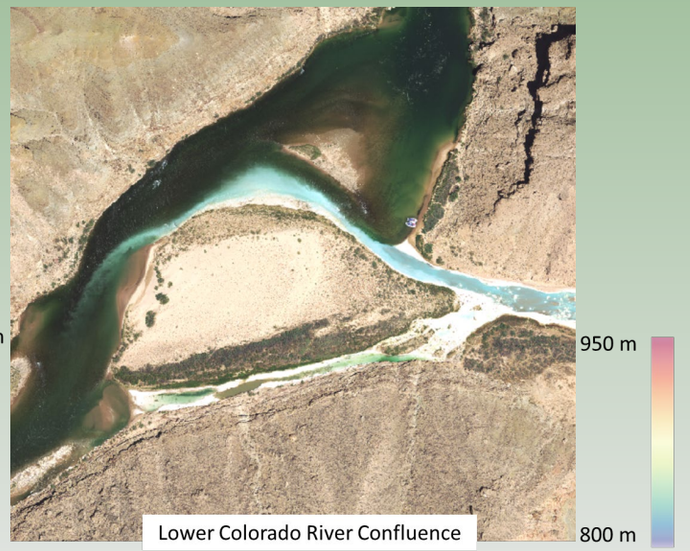
The End and Next Steps

Thanks for listening and remember it is not too early to begin planning for the next overflight which could occur in 2025 or 2026 during the next Triennial Workplan!

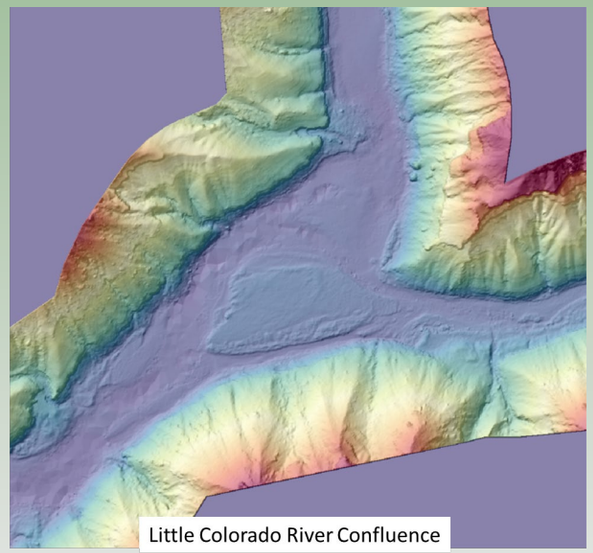

Glen Canyon Dam



Glen Canyon Dam



Lower Colorado River Confluence


Little Colorado River Confluence


Lava Falls Rapid


Diamond Creek Boat Ramp

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