



**ARCTIC**  
**SDI** Arctic Spatial  
Data Infrastructure

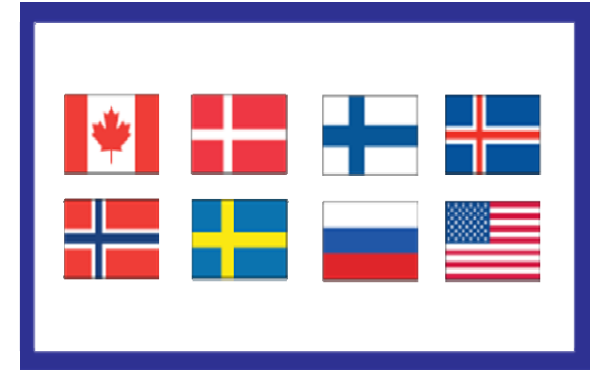
## ***Pan-Arctic Digital Elevation Model***

***- International Collaboration in Generation of ArcticDEM***

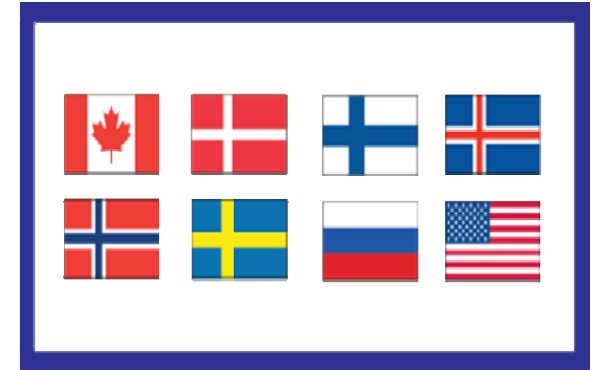
**ESRI International Users Conference,  
June 30, 2016**

**Tracy Fuller, USGS Pan-Arctic DEM Technical Lead,  
Alaska Mapping Initiative Program Manager**

- Arctic Council Initiative, U.S. Chairmanship 2015-2017, Sponsored under 'Address the Impacts of Climate Change' banner
- Proposal Accepted by Arctic Council Spring 2015
  - Improve public access to high resolution Arctic elevation data
  - Single point of access
  - Arctic Spatial Data Infrastructure, representing the national mapping agencies of the eight Arctic nations, coordinate international support to the project
  - Arctic Council 'Conservation of Flora and Fauna' Working Group (CAFF) to monitor progress
  - USGS Associate Director and current Arctic SDI Chair Kevin Gallagher given oversight responsibility
  - June 2015 Arctic SDI approves initial investigations into inventorying and harmonizing Arctic elevation



- **Initial Concept and Investigations**
  - Integrate data from individual Arctic Nations into a single resolution and format
  - Inventoried available data sets from Canada, Denmark/Greenland, Finland, Iceland, Norway, Sweden, Russia, and United States
  - Wide variety of ages, resolutions, technologies
- **Polar Geospatial Center ArcticDEM Product**
  - Announced by U.S. President September 2015
  - Unique solution to the original initiative
  - Funded by National Science Foundation, source imagery provided under National Geospatial Intelligence Agency's DigitalGlobe imagery license

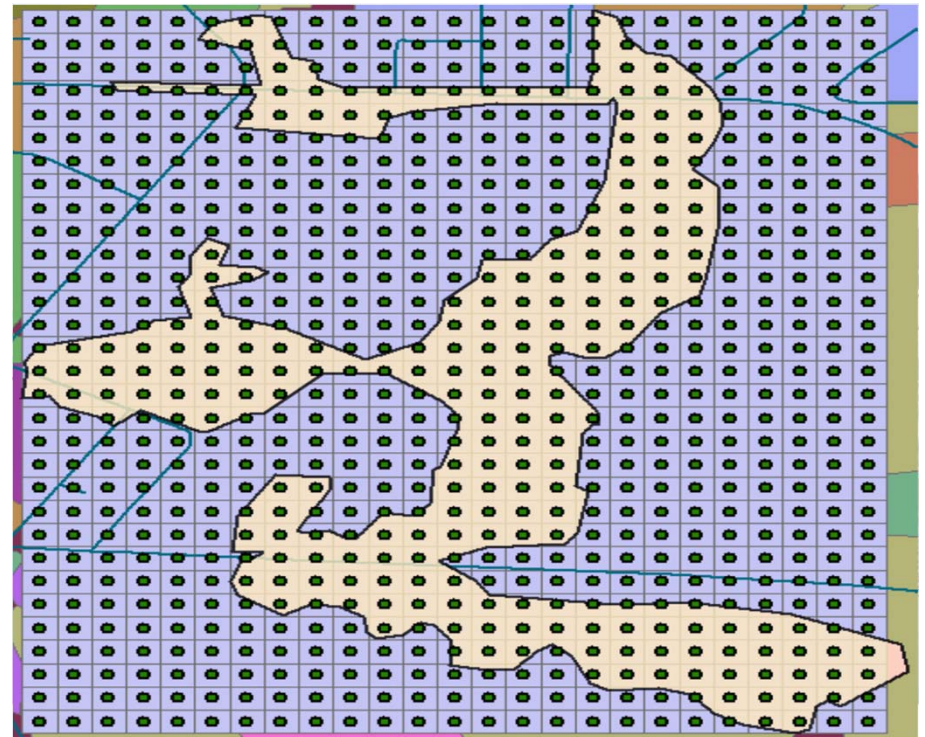


# Digital Elevation Model

*A Digital Elevation Model, or DEM, is a digital representation of terrain*

- One common DEM structure is a regular grid of elevation heights
- The ground distance between points is called DEM density or resolution (examples: 1000m, 100m, 30m, 10m, 5m, 2m – lower resolution means more detail)

340	335	330	340	345
337	332	330	335	340
330	328	320	330	335
328	326	310	320	328
320	318	305	312	315

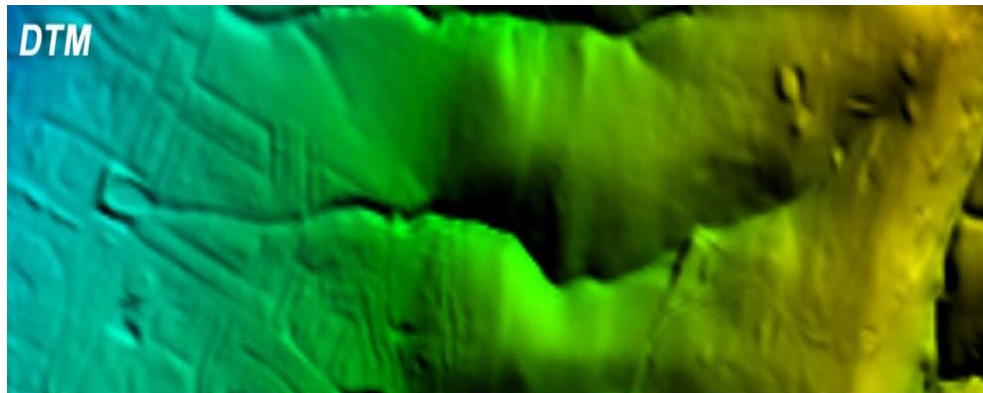


(graphics from MIT Libraries)

## Digital Elevation Model Subtypes

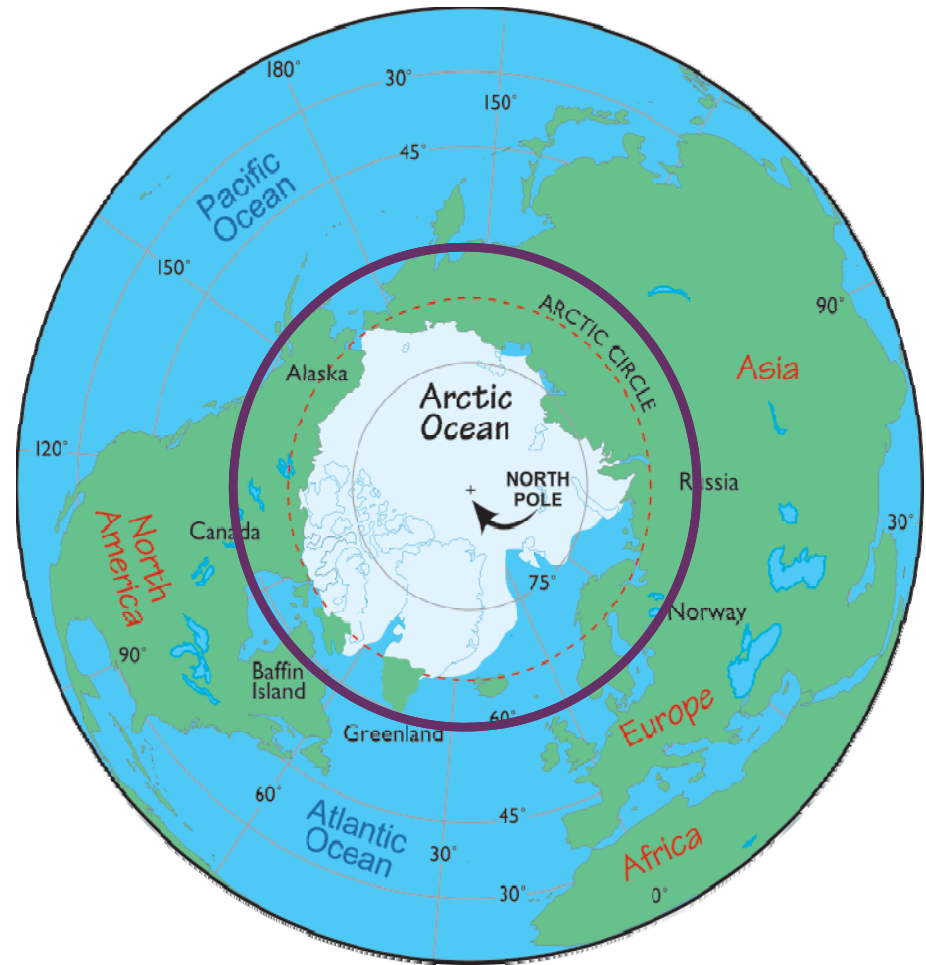
### *Digital Surface Model (DSM) and Digital Terrain Model (DTM)*

- DSM shows ‘tops of trees and structures’, DTM removes cover to show ‘bare earth’
- Both are important for modeling and mapping applications



# PGC Arctic Elevation Data

- PGC has branded its product 'ArcticDEM'
- 2m elevation data is being created for the first time over the entire Arctic 60-degrees and north, and for all of Alaska, Greenland, and the Russian Kamchatka Peninsula
- DSM product is automatically derived from satellite optical imagery
- All the data will be available to the public for free, unrestricted use



# *The ArcticDEM*



Paul Morin  
Polar Geospatial Center  
University of Minnesota



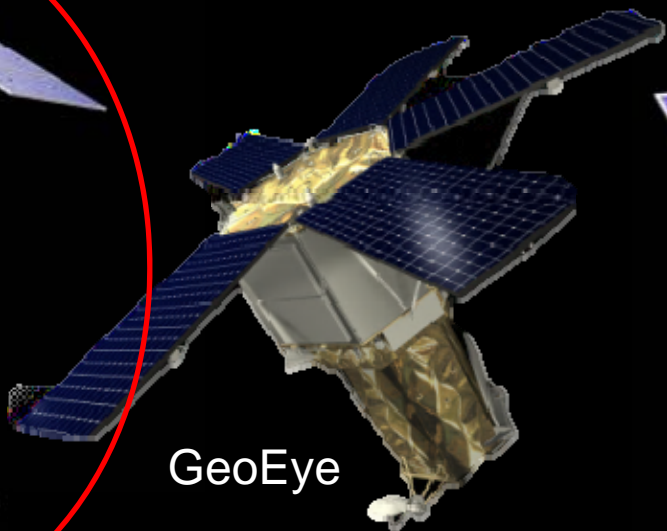
Cornell University

Ellef Ringers Island, Nunavut

# The DigitalGlobe Satellite Constellation



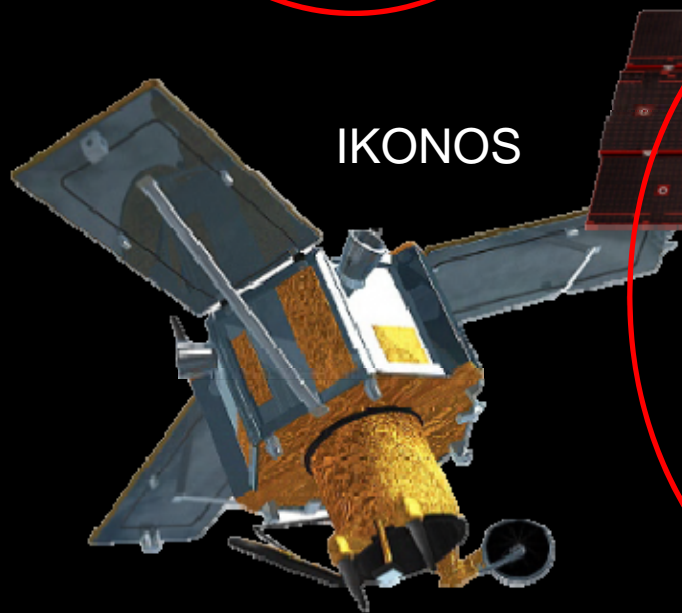
WorldView-2



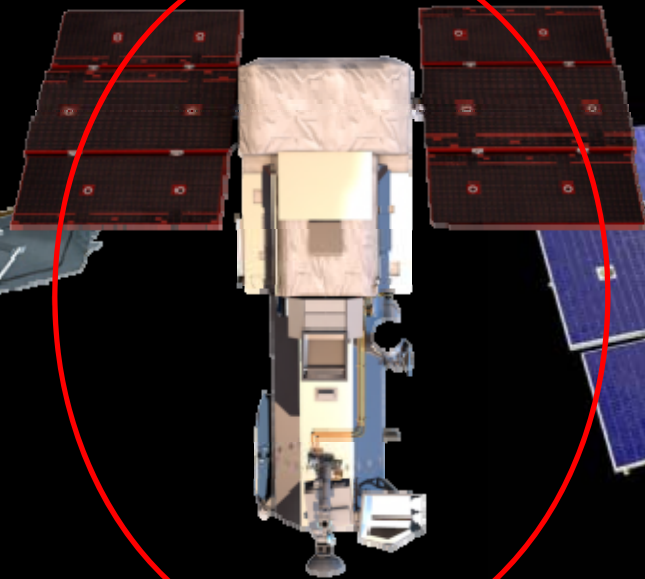
GeoEye



QuickBird



IKONOS

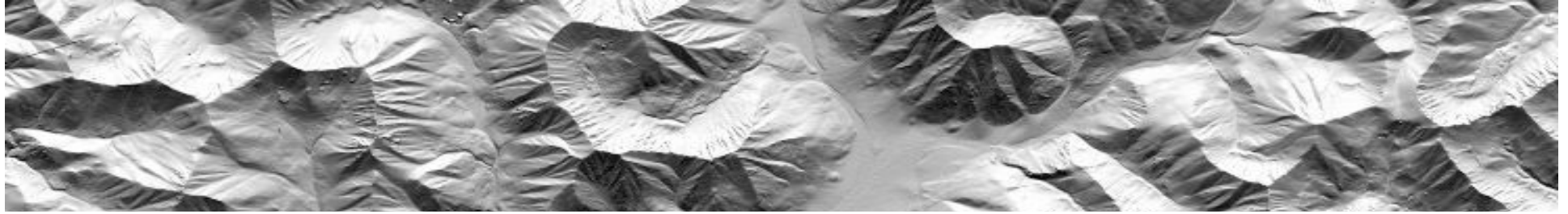


WorldView-3



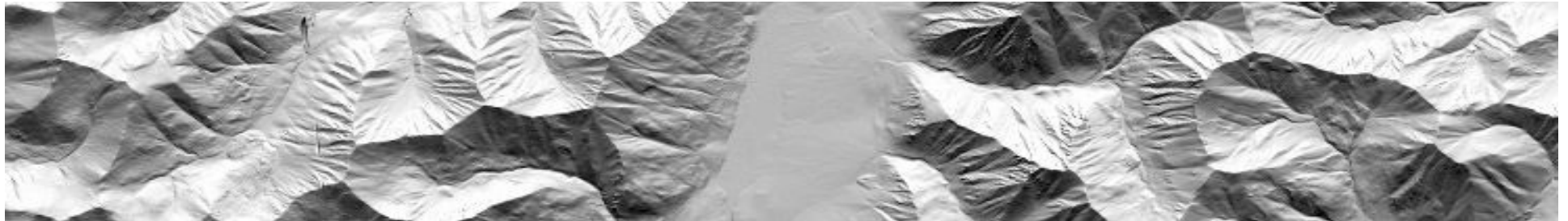
WorldView-1





SETSM:

## Surface Extraction with TIN-Based Search-space Minimization



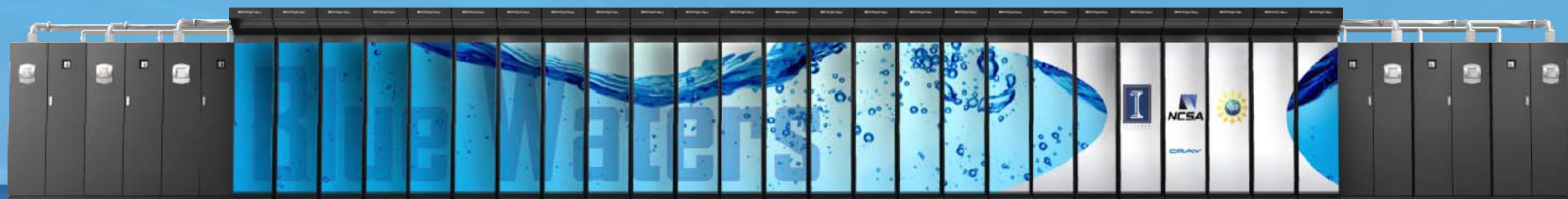
- Stereoscopic Terrain Modeling Software
- Fully Automated
- Uses no *A Priori* Information (no seed DEM required)
- Can run on any High Performance Computer
- Self-contained C programming language
- Open Source release in near future



# BLUE WATERS

SUSTAINED PETASCALE COMPUTING

## Blue Waters System Overview



GREAT LAKES CONSORTIUM  
FOR PETASCALE COMPUTATION

CRAY

## What the Sub-meter Polar Imagery Collection Looks Like



*Servers at OIT data center wrapped for cooling*

# Novaya Zemlya, Russia



Made from DigitalGlobe Imagery

# The Limitations of this Strategy

ArcticDEM is a Digital Surface Model. Bare ground is not possible.

This is optical imagery from orbit. There will be holes from clouds and other atmospheric obstructions.

Collection continues while the sun is  $7^\circ$  above the horizon so imagery is a mix of seasons and years.

There is competition for the DG constellation in Alaska and elsewhere.



# The Strengths of this Strategy

NGA and DigitalGlobe have high collection capacity at high latitudes. Holes can be filled when identified.

Collection is constant while the sun is  $7^\circ$  above the horizon.

The collection is time-dependent. Imagery is a mix of seasons and years.

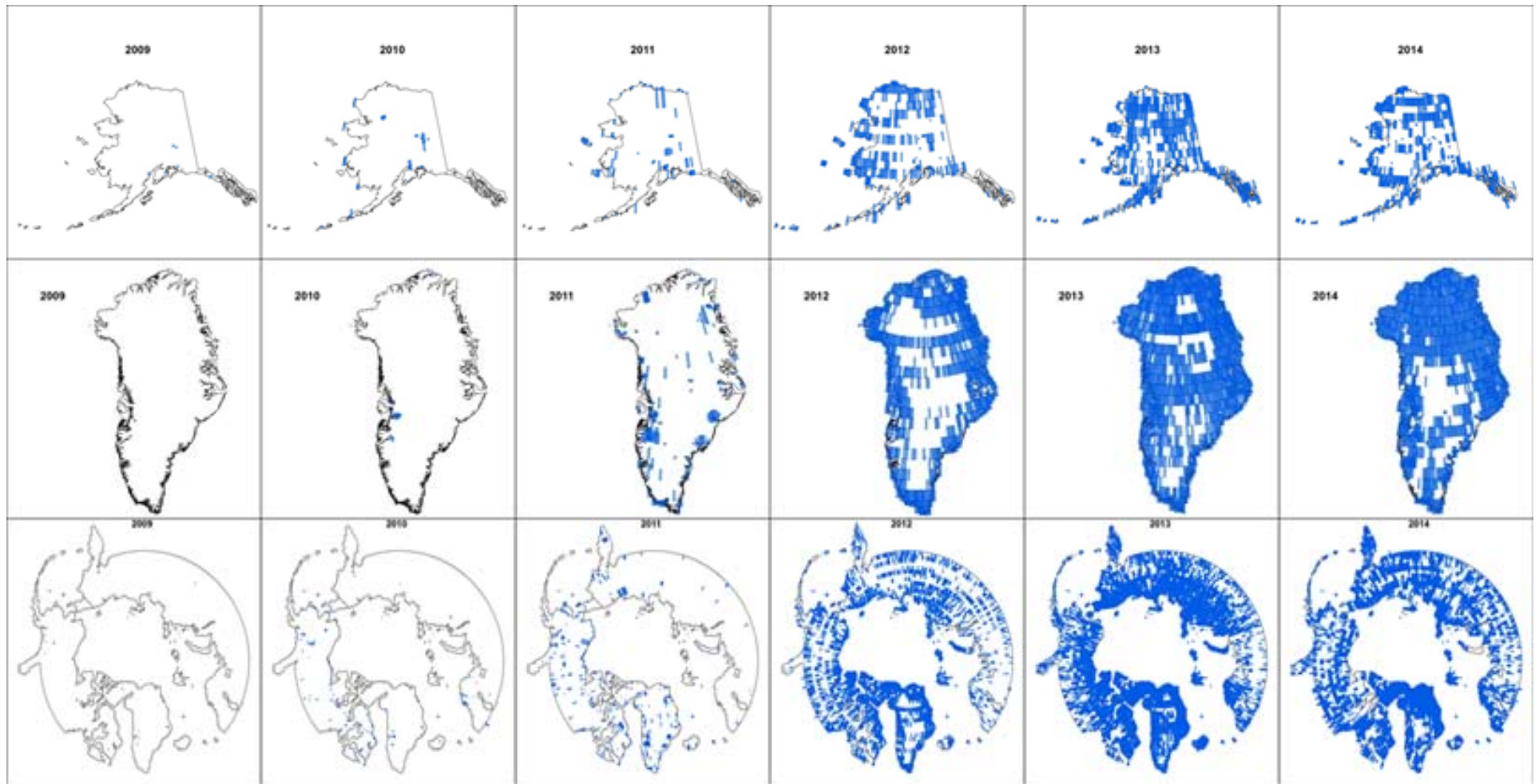
New imagery can be processed as it is tasked.

As ground control improves the accuracy can be improved.

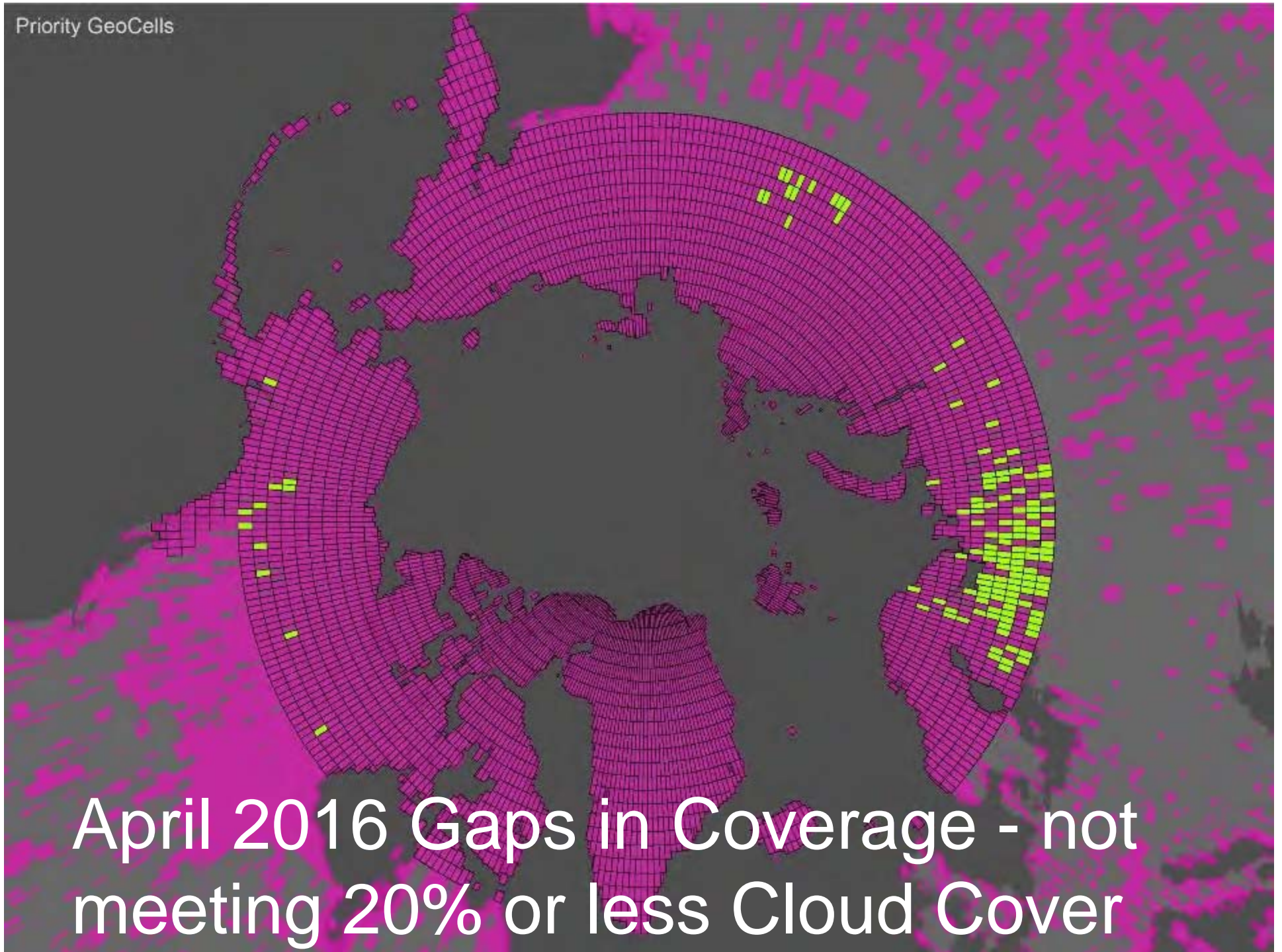
ArcticDEM is a Digital Surface Model. Canopy can be measured.



# Stereo Coverage by Year



Priority GeoCells







# USGS and Arctic SDI Support of PGC ArcticDEM



## USGS

- **Coordinate international support to Polar Geospatial Center**
  - **Organize a series of workshops with Arctic nation mapping representatives and Polar Geospatial Center (2 workshops held to date)**
  - **Interface between Arctic SDI nations and PGC**
- **Produce progress reports for CAFF and Arctic Council**
- **Coordinate international requirements gathering activities**

## Arctic SDI

- **Arctic nations have provided control data (control points, lidar, linear elevation models) and GIS data (shorelines) to improve ArcticDEM**
- **Arctic nations reviewed early data samples and reported issues to PGC, algorithm adjusted accordingly**
- **Some Arctic nations will edit PGC data as needed and create an improved national product for public release after ArcticDEM is delivered (Canada, Greenland, Iceland, Svalbard Norway, Aleutians)**

# Pan-Arctic DEM Workshops

**Workshop I held in Waterloo, Canada October 2015**

**Workshop II held in St. Paul, Minnesota at Polar Geospatial Center  
April 2016**

Attendees: Elevation experts and Arctic SDI National Contact Points from Arctic nations, PGC technical experts and managers, NSF and NGA program managers, ESRI

## Lessons Learned

- Some known issues with the data (cloud cover, data voids, snow cover)
- Alaska will be delivered summer 2016
- Remainder of Arctic will be complete by summer 2017
- NGA is tasking DigitalGlobe satellites to fill any gaps in imagery
- Auto-correlation processing algorithm is stable
- PGC will deliver the individual strips of data and mosaic product
- ESRI considering distribution through ESRI ImageService
- PGC not currently funded past initial ArcticDEM delivery
- PGC recently funded to create Antarctic DEM

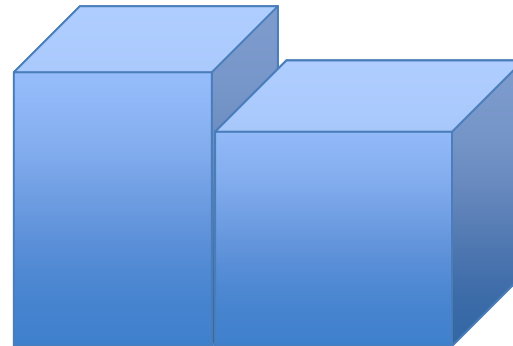
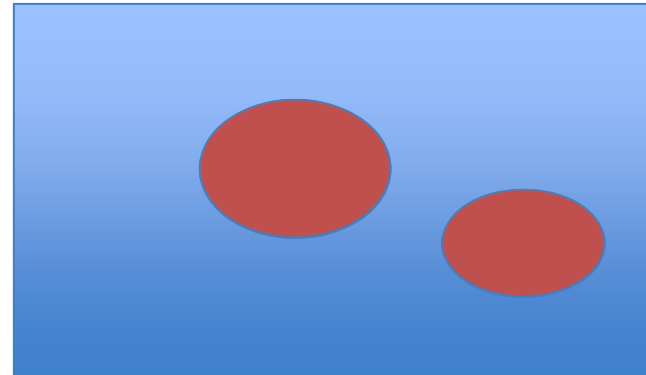


- **Tentative Schedule:**
  - **Alaska in summer 2016**
  - **Remainder by summer 2017**
    - **Iceland**
    - **Greenland**
    - **Sweden, Norway, Finland**
    - **Canada**
    - **Russia**

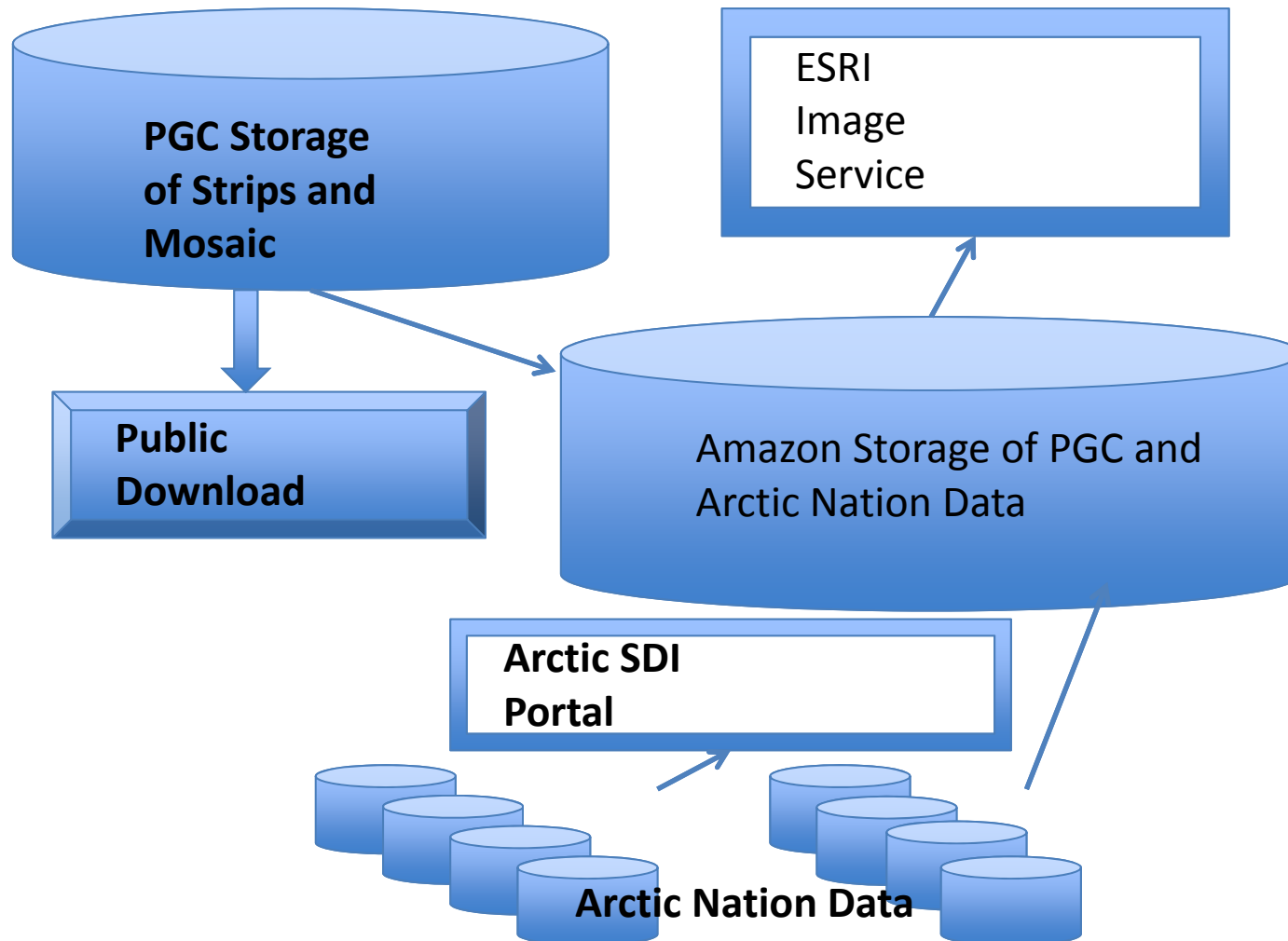
- **Source Imagery Status**
  - **PGC accepts images with up to 20% cloud cover**
  - **Snow-season imagery dominates the collection (best opportunity for cloud free images)**
  - **Intense satellite tasking ongoing to fill any remaining holes in coverage (PGC assumes they will have full coverage for 2017 Arctic DEM release)**
  - **NGA will task repeat scenes over areas with poorest quality imagery after gaps are filled**

- **Deliverables**
  - **PGC will deliver all 17km x 120km imagery strips for download (many strips will have repeat coverage)**
  - **PGC will create a final mosaic for download: merge strips into larger collections, provide 1km x 1km tiles, polar geographic projection, geoTIFF format**
  - **ESRI will offer image service of all the data; data currently stored on the Amazon cloud (in discussions with Amazon to make permanent)**

- **Data Errors Observed**
  - **Some void areas in data: clouds, shadows in canyons, high reflectance on some water bodies**
  - **Land surface showing over shallow water, over some lakes with high reflectance**
  - **Snow cover**
  - **'Walls' at strip edges (strips auto-correlated independently)**



- **Conceptual Data Distribution through University of Minnesota, ESRI ImageService, and Arctic SDI Portal**



## **Arctic SDI Suggested MOSAIC Implementation Rules**

**In priority order:**

**No voids**

**No snow**

**No leaves**

**Most current scene available**

**Complete tiles**

**But don't patch with other data sets (GIMP, Aster, etc)**

**Use scenes that require smallest size of void patches as possible**

**Similar source date over similar Land Cover/Land Use**

**(For glacial monitoring you wouldn't want to use multiple years)**

**Ensure that historical versions are always available**



## 1) Endorse PGC ArcticDEM as 1<sup>st</sup> Generation Pan-Arctic DEM Solution

- Formally announce support for this solution to Arctic Council

## 2) Arctic Countries Support PGC Gen1 Effort

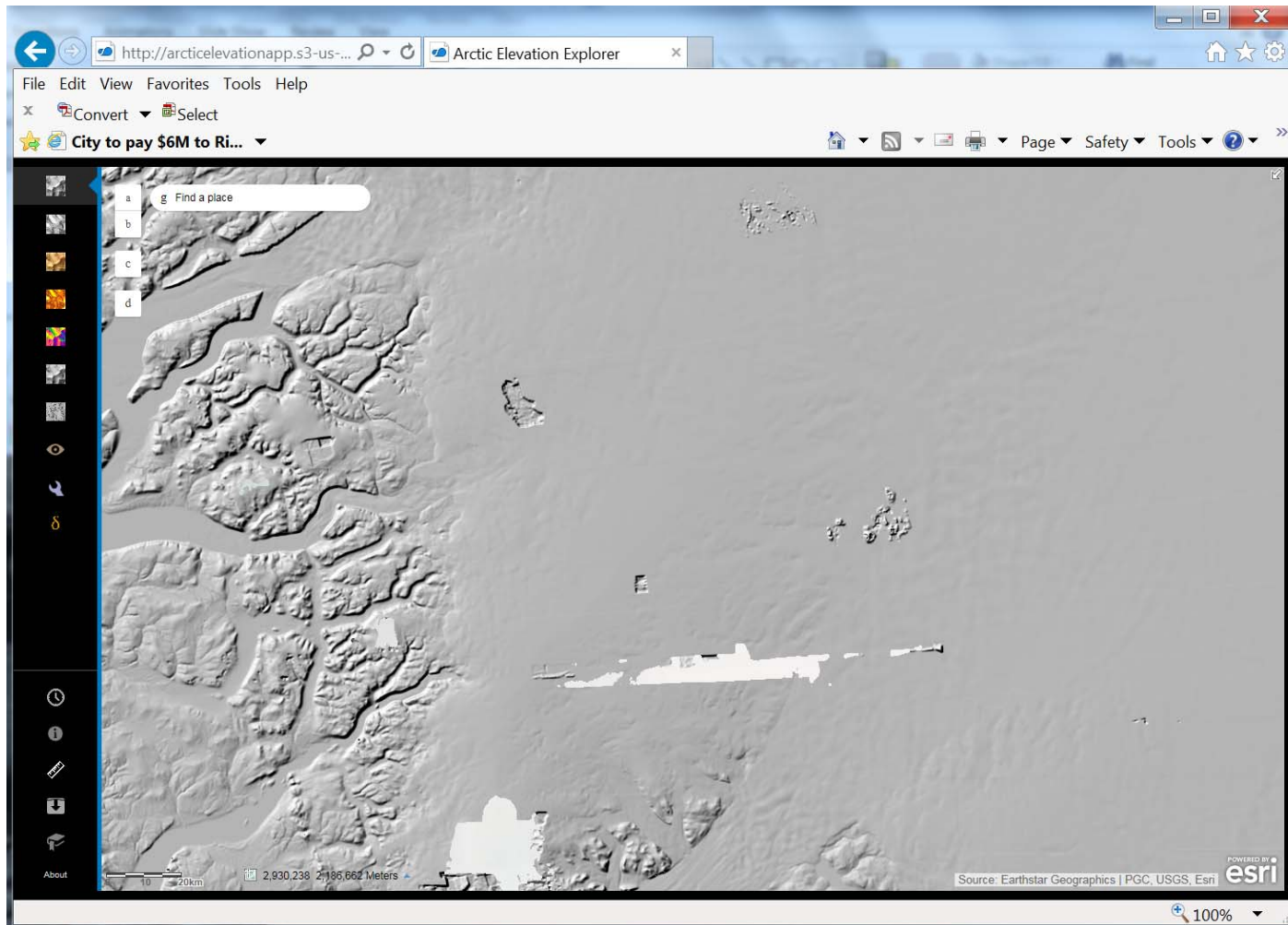
- Countries that have the capacity and authority, not mandatory
- Provide control data, shorelines, data review and comment

## 3) Consider 2<sup>nd</sup> Generation Pan-Arctic DEM using Arctic Nation Data

- Will require significant effort from Arctic SDI Technical Committee
- Several countries need to complete collection efforts (3-4 years) or complete editing of PGC ArcticDEM data
- Investigate after final delivery of ArcticDEM in summer of 2017

- Arctic SDI Board will formally vote on recommendations at June meeting
- Several have voiced approval for Recommendations 1 and 2
- Need to weigh Recommendation 3 against other Arctic SDI objectives – (wait on Board vote before starting any preliminary investigations)

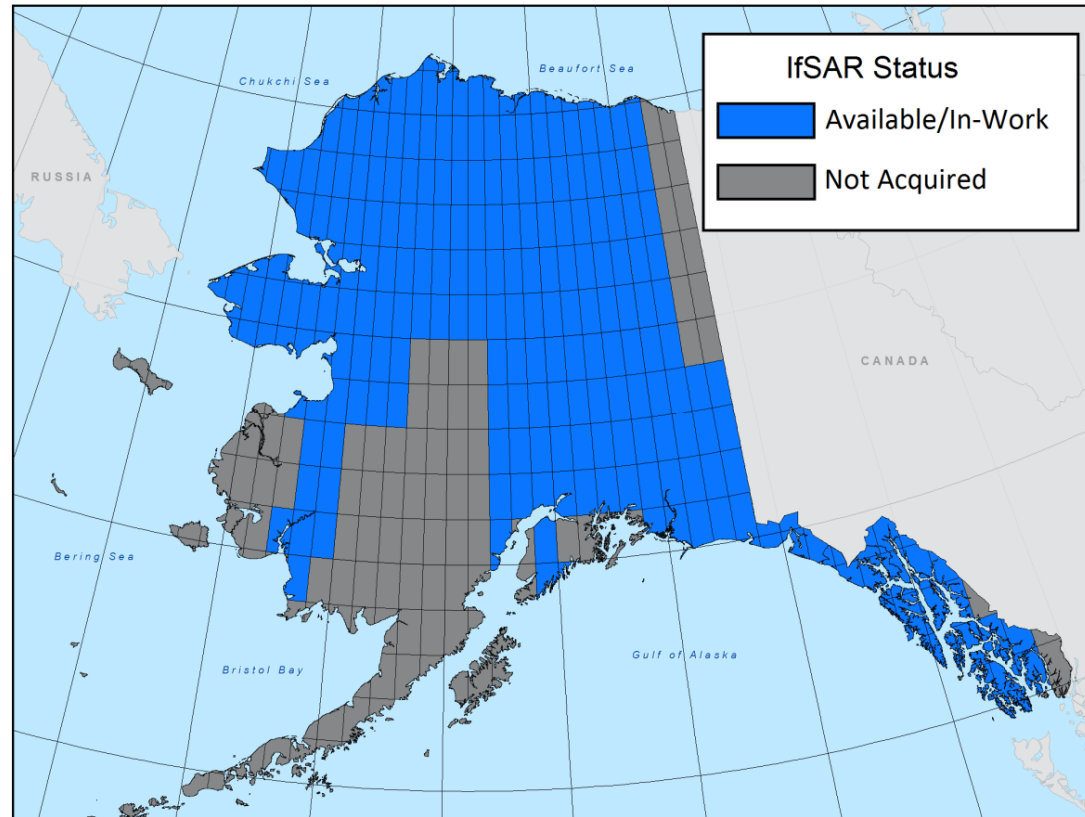
# ESRI ARCTIC EXPLORER (Image Service PGC ArcticDEM)



# + April 2016 Alaska IfSAR Status

- IfSAR is available or in-work for 69% of Alaska
- In FY15 partner agencies contributed \$7.6M
- FY16 contributions to date total \$6.0M
- Agencies seeking EOY funds to complete NE
- Completing IfSAR collection for all cells above 65-degrees north is a goal during the 2015 - 2017 Arctic Council Chairmanship

Alaska IfSAR Elevation Status



# ESRI IfSAR EXPLORER (Image Service AK IfSAR Data)

