Alaska
Geographic
Data
Committee

USGS Task Order, Alaska DEM – Phase II
Alaska DEM Funding and Implementation Plan

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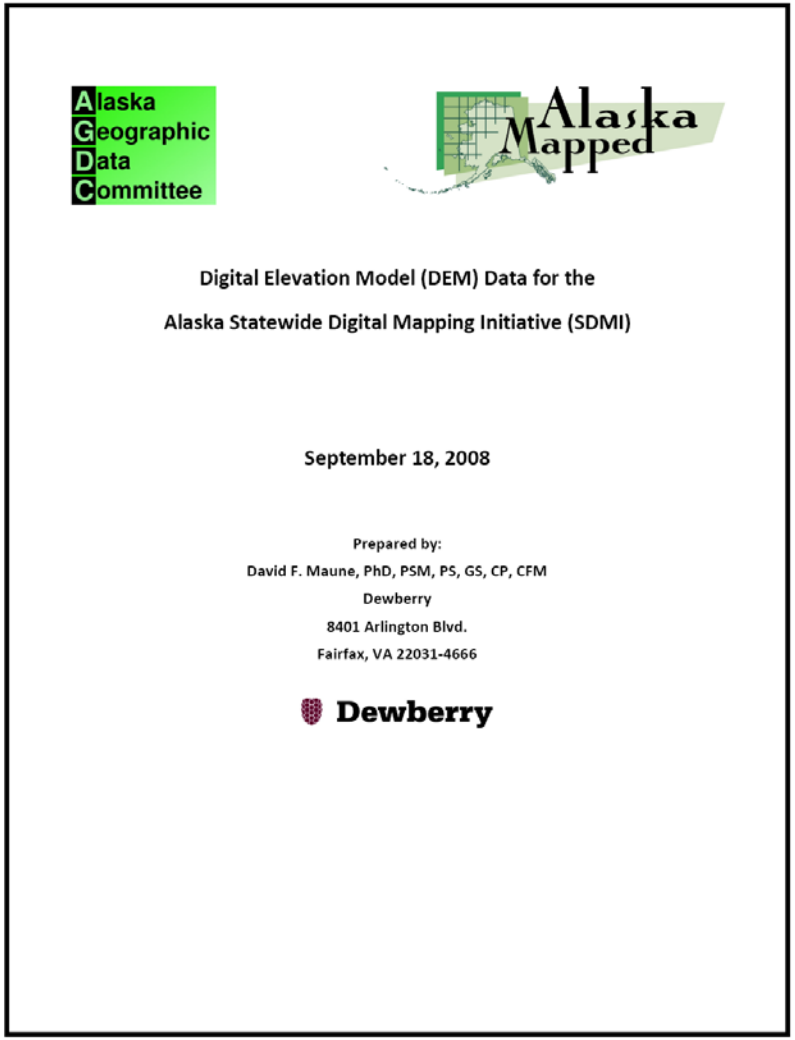
Alaska DEM Whitepaper (Phase I)



Alaska Geographic Data Committee

Alaska Mapped

Digital Elevation Model (DEM) Data for the

Alaska Statewide Digital Mapping Initiative (SDMI)

September 18, 2008

Prepared by:

David F. Maune, PhD, PSM, PS, GS, CP, CFM

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Dewberry

- Identified statewide requirements and alternative solutions for obtaining accurate and current digital elevation data for Alaska.
- Obtained strong concurrence from NDEP and NDOP in August.

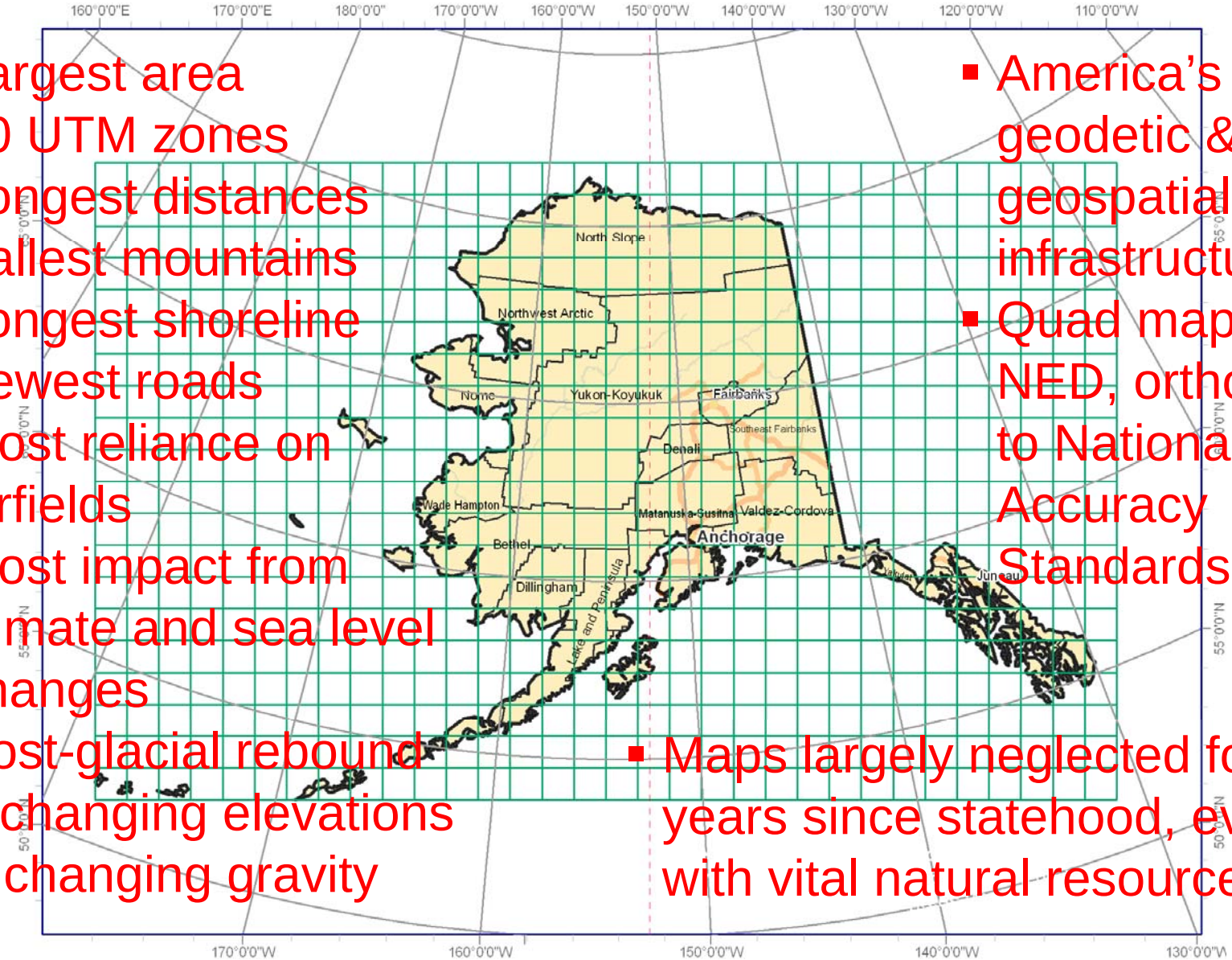
2nd Edition, 2007

1. Introduction to DEMs, 3-D Surface Modeling, Tides
2. Vertical Datums
3. Accuracy Standards
4. National Elevation Dataset
5. Photogrammetry
6. IFSAR
7. Topographic & Terrestrial Lidar
8. Airborne Lidar Bathymetry
9. Sonar
10. Enabling Technologies
11. DEM User Applications
12. DEM Quality Assessment
13. DEM User Requirements
14. Lidar Processing & Software
15. Sample Elevation Datasets

Why Alaska is Different and Changing

Ships can now transit N. Atlantic ↔ N. Pacific around N. Slope

- Largest area
- 10 UTM zones
- Longest distances
- Tallest mountains
- Longest shoreline
- Fewest roads
- Most reliance on airfields
- Most impact from climate and sea level changes
- Post-glacial rebound = changing elevations & changing gravity



- America's worst geodetic & geospatial infrastructure
- Quad maps, NED, orthos <u>not</u> to National Map Accuracy Standards
- Maps largely neglected for 50 years since statehood, even with vital natural resources

Alaska Geoid errors ≈ 2 meters

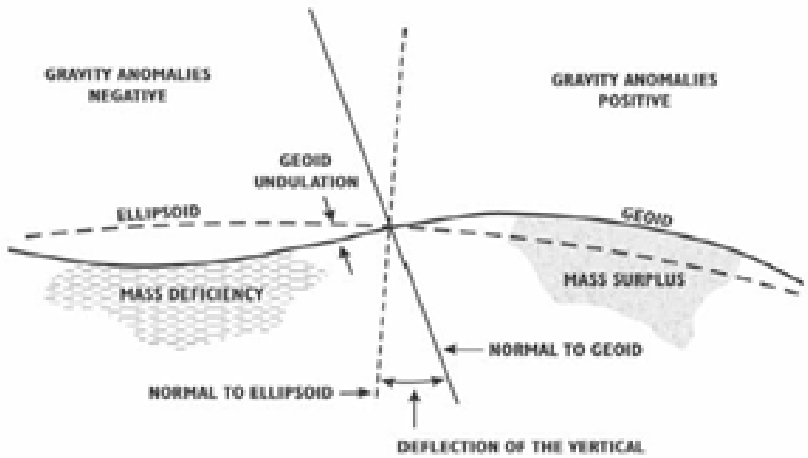


Figure 3. Ellipsoid, geoid, and geoid undulation (geoid height).

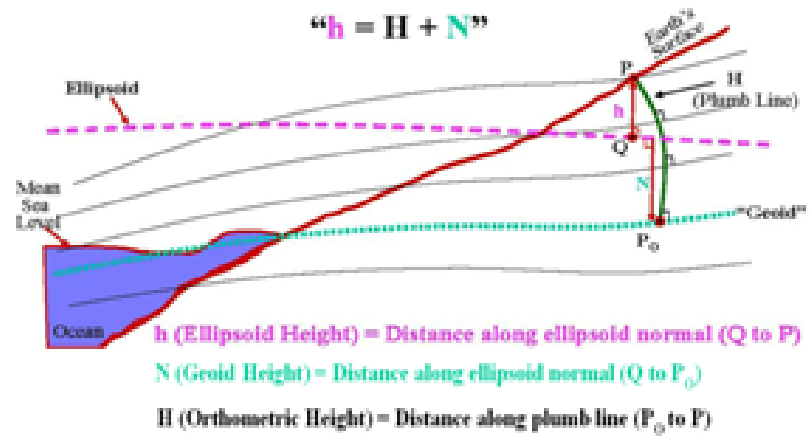
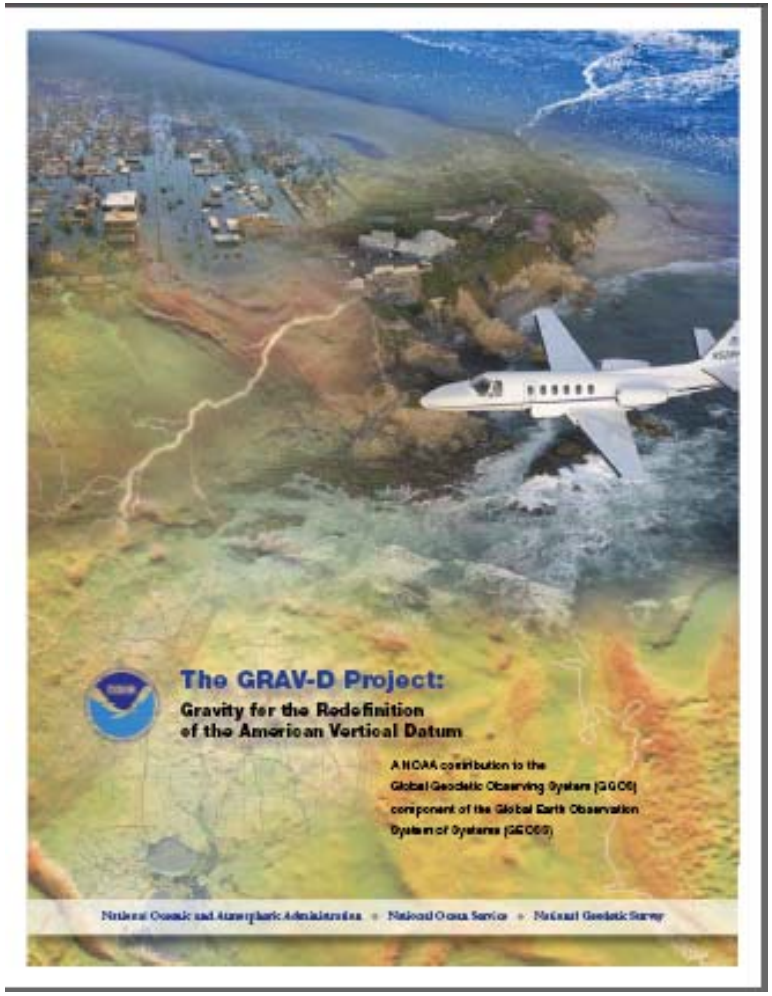


Figure 4. Geodetic formula for conversions between ellipsoid heights and orthometric heights.

Campaign I: High-Resolution Snapshot of Gravity



Phase I: Testing

Phase II: Operational Data Collection

1. Alaskan littoral regions excluding Aleutians
2. Southern Alaska
3. CONUS littoral regions
4. Hawaii & Aleutians
5. Inland CONUS
6. Northern Alaska

NO DEDICATED FUNDING

Figure 6. Sparse CORS Network in Alaska

Receiver Sampling Rate

1 sec | 5 sec | 10 sec | 15 sec | 30 sec | Show All | Show Decommissioned Sites

Alaska compared with other States

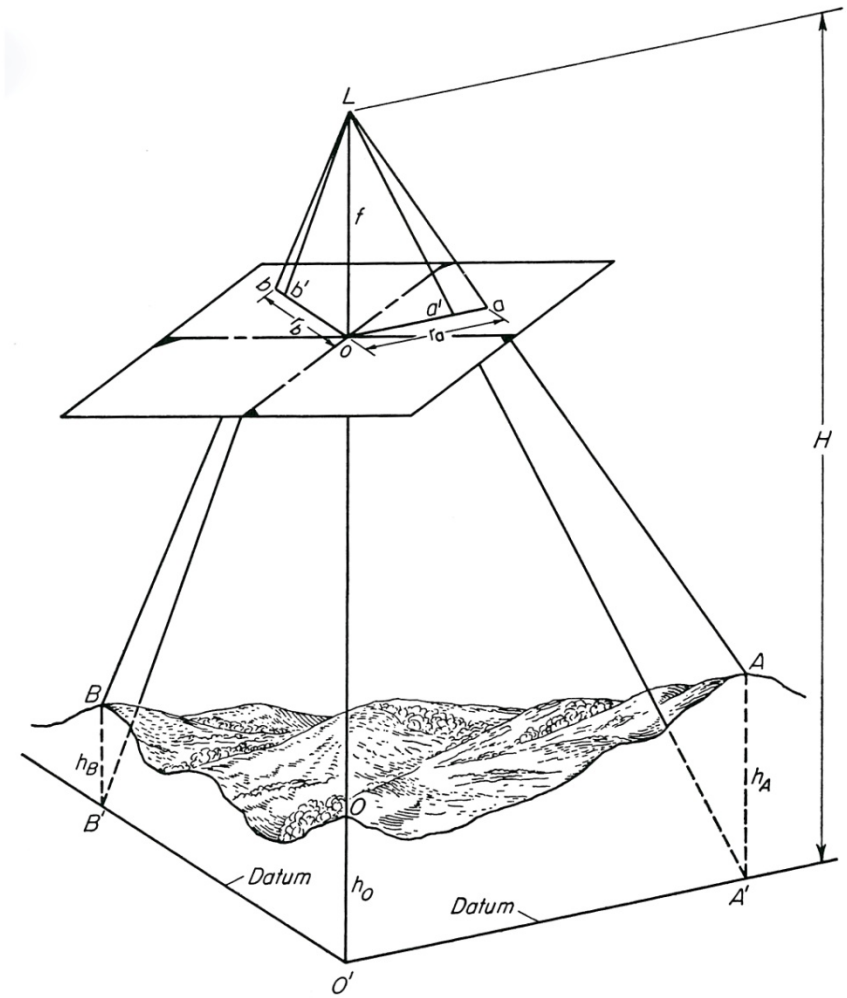
- Smaller scale (1:63,360) topographic quads in Alaska, and many do <u>not</u> satisfy National Map Accuracy Standards (NMAS)
- National Elevation Dataset (NED) has huge errors:
  - **Horizontal errors: several miles in some places (errors are 100 times larger than per NMAS)**
  - **Vertical errors: hundreds of meters too low**
- Few roads; rely on air transportation; even the state capitol, Juneau, is not accessible by road.
- Aeronautical charts, DEMs and eTOD data are critical to all aviators, including DOD and DHS statewide.
- Cannot accurately orthorectify images using the NED

Quotes from experienced pilot who lost many pilot friends in Alaska aviation accidents

- "On the track from Fairbanks to Kobuk, there is a <u>mountain that is 3,000 feet higher</u> than in the sectional aeronautical map … <u>absolutely certain it is more than two miles displaced</u>. It was very impressive, if flying IFR and trusting the map we would have flown right into it."

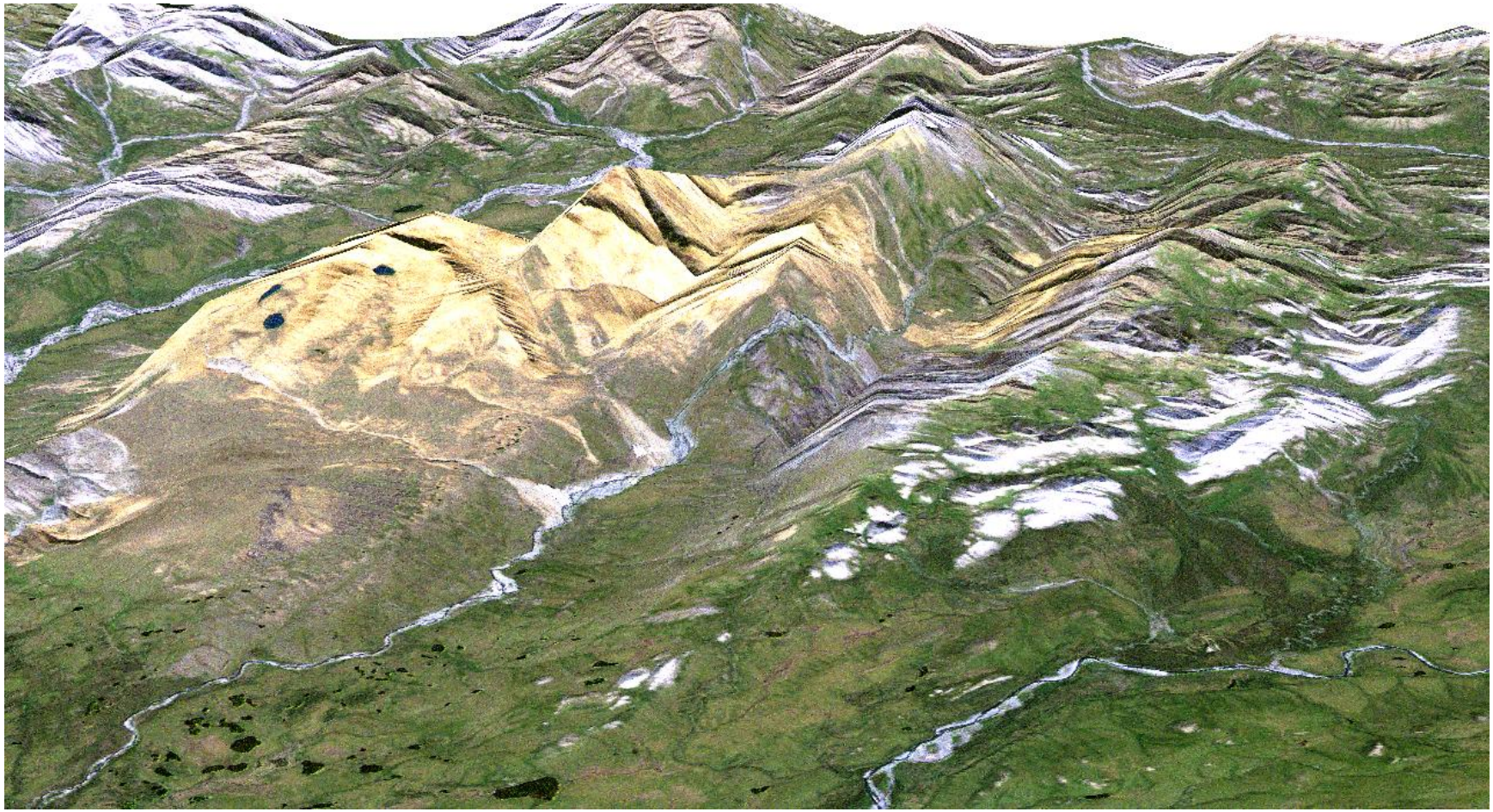
- "You'll find most mountains 300 feet too small."
- "Wolverine Mountain and Angutikada Peak are 'way off' in the sectionals."
- Appendix B in whitepaper provides many other examples.

Alaska orthorectification problems



- Normally images can be draped over a DEM from the NED for orthorectification
- Won't work in Alaska when NED errors are:
  - 100's of meters vertical
  - 1,000's of meters horizontal
- Need to first correct Alaska NED …

… to avoid this kind of problem (Western Alaska)



Kevin Engle – UAF GINA: http://www.gina.alaska.edu

User Group 1: Aviation Safety

Interviewed

- Steve Colligan
- Lars Gleitsmann
- Nick Mastrodicasa
- George Sempeles (FAA)

Mid-accuracy (20-ft) equivalent contour accuracy is required for Alaska Area 2 IFR sites

Alaska Applications/Benefits

- FAA compliant Electronic Terrain and Obstacle Database (eTOD) required for navigation in Alaska during extensive periods of limited visibility where Instrument Flight Rules (IFR) are used.
- 20- ft contour accuracy DSMs and DTMs needed for Aviation Safety in Area 2 terminal control areas for airfields throughout Alaska
- 200-ft contour accuracy (or better) DSMs and DTMs statewide for Area 1 requirements
- Terrain avoidance; mountain passes, float plane needs are unique for Alaska

ICAO Area 1 and Area 2 standards

Because the Shuttle Radar Topography Mission (SRTM) did not collect elevation data north of 60° north latitude, and because of the major known horizontal and vertical errors in the NED, the U.S. currently does not satisfy the relatively simple Area 1 standard in Alaska (equivalent to 200-ft contour accuracy).[1] Neither is the U.S. prepared to satisfy the more-demanding Area 2 standard in Alaska (equivalent to 20-ft contour accuracy) which pertains to IFR site terminal control areas (circles with radius of 45 Km).

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[1]During user interview on August 5, 2008, Mr. George P. Sempeles, FAA ATOR-R, Aeronautical Information Services, Cartographic Standards, stated that there is a serious lack of reliable elevation data in Alaska and that he agreed with the concerns raised by the Alaska aviation community. He stated that the area of Alaska north of 60° north latitude does not comply with ICAO Area 1 standards and that elevation data equivalent to airborne IFSAR statewide would be needed to bring Alaska into conformance with Area 2 standards, stating that it makes no sense to have high accuracy elevation data within those circles and low accuracy elevation data elsewhere.

ASTER GDEM may satisfy "Area 1" but not "Area 2" requirements.

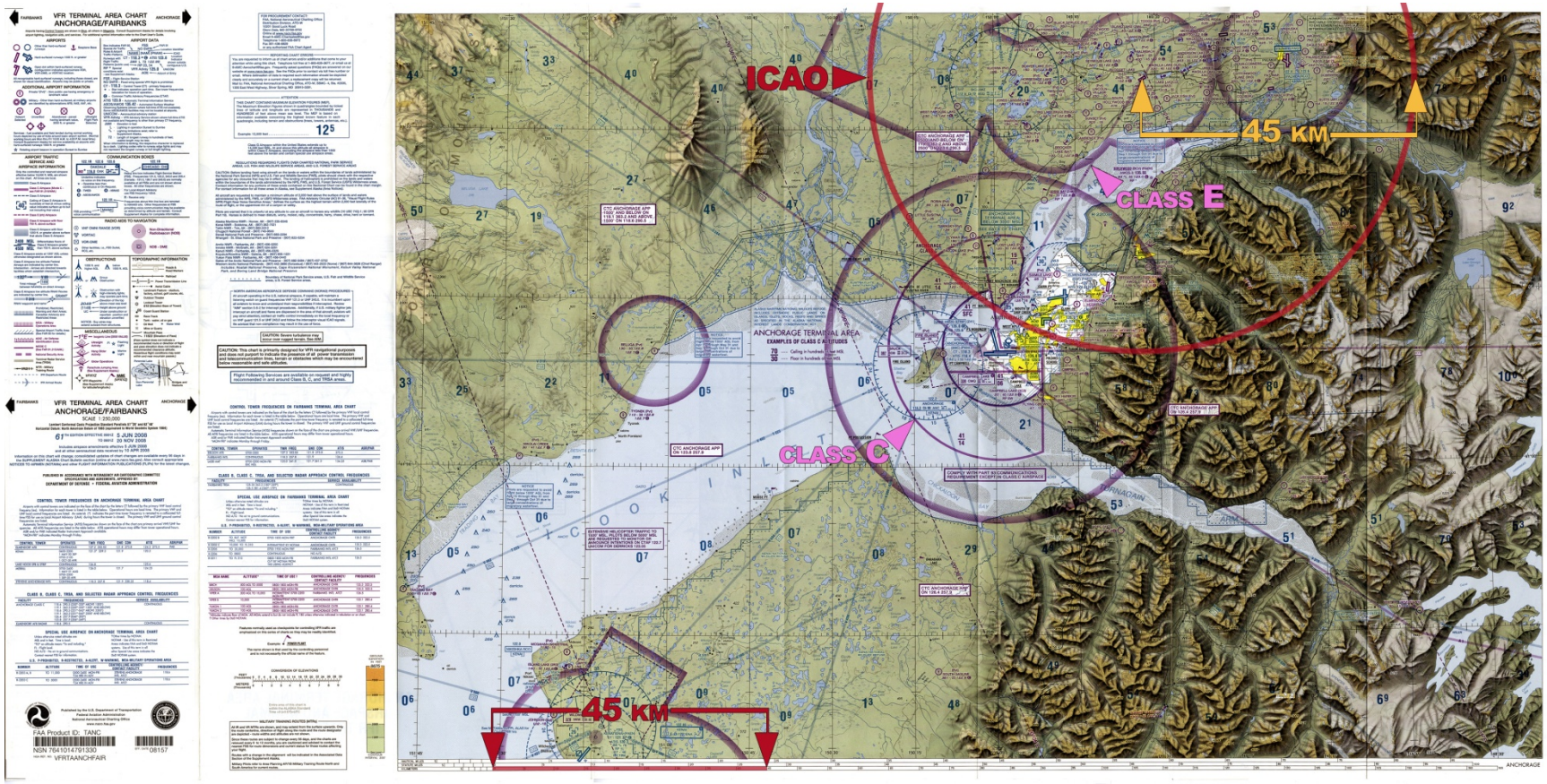
Alaska satisfies neither Area 1 nor Area 2

To satisfy identified user requirements for eTOD data, while taking into account cost-effectiveness, acquisition methods and data availability, the data are to be provided according to four basic coverage areas:

- Area 1 has a coverage over the whole territory of a state or country, including aerodromes/heliports.
- Area 2 covers the established terminal control areas, not exceeding a 45 km radius from the aerodrome reference point (ARP), to coincide with the existing specification for the provision of topographical information on the Aerodrome Obstacle Chart.
- Area 3 covers the area which is within the specified distances from the edges of a defined aerodrome or heliport surface movement area.
- Area 4 is restricted for use only for those runways where precision approach Category II or III operations have been established.

ICAO Doc 9881 provides the minimum user requirements applicable to the origination and publication of terrain data from creation through the entire life cycle of the data. It provides a minimum list of attributes associated with the terrain data and a description of associated errors that may need to be addressed. Any data processing must be accomplished in accordance with known and established quality processes and procedures.

VFR Terminal Area Chart showing red circle within which DEM w/20-ft contour accuracy would be required when landing under IFR conditions at the Wasilla Airport



What is the eTOD?

The Electronic Terrain and Obstacle Database (eTOD) is an internationally agree-on standard to provide a safe terrain database for safe flying and navigation under Instrument Meteorological Conditions (IMC) when pilots cannot see the terrain at all due to night and clouds or other weather such as heavy rain and snowfall.

When Visual Flight Rules (VFR) cannot be safely followed, and especially during emergency air evacuations at remote villages, aviators then operate under Instrument Flight Rules (IFR) designed to keep aircraft from unintentionally flying into obstacles due to navigation errors.

The need for elevation data to create a reliable and compliant FAA eTOD for navigation in Alaska, during periods of limited visibility, has never been greater. IMC flying conditions have to be coped with in Alaska on a regular basis for airfields throughout the state, even for airfields that are not part of the FAA's 148 IFR sites. Accurate DEMs are vital for flight planning, terrain avoidance, transiting through mountain passes, and landing of float planes on rivers and other water bodies. DEMs are also used for pilot training and simulators.

Terrain data for eTOD

Note: Obstacles require “boots on the ground” surveys

Guidelines for Electronic Terrain, Obstacle and Aerodrome Mapping Information (Doc 9881)

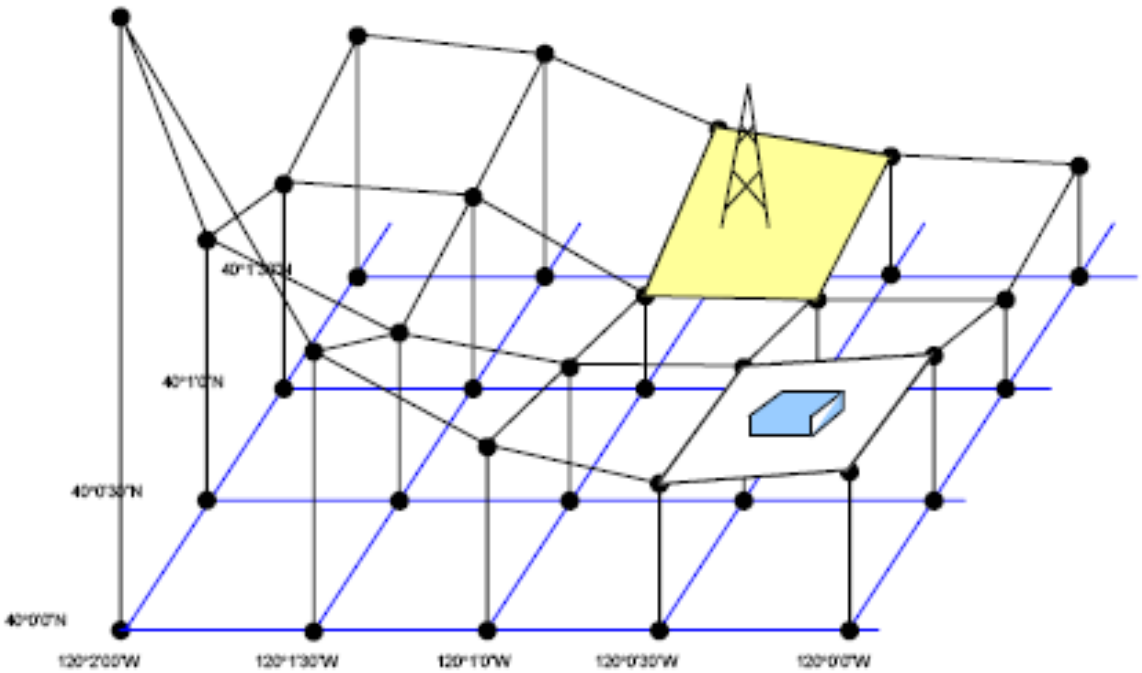


Table 2. ICAO DEM Requirements

ICAO	Area 1 Standards	Area 2 Standards
Post Spacing	3-arc-seconds (≈90 meters)	1-arc-second (≈30 meters)
Vertical Accuracy (LE90)	30 meters	3 meters
Equivalent Contour Interval	60 meters (200 ft)	6 meters (20 ft)
Vertical Resolution	1 meter	0.1 meter
Horizontal Accuracy (CE90)	50 meters	5 meters
Confidence Level	90%	90%
Compliance Date	November 20, 2008	November 20, 2010

In addition to SRTM (south of 60° north latitude) entire world may satisfy this Area 1 requirement when ASTER GDEM data is available

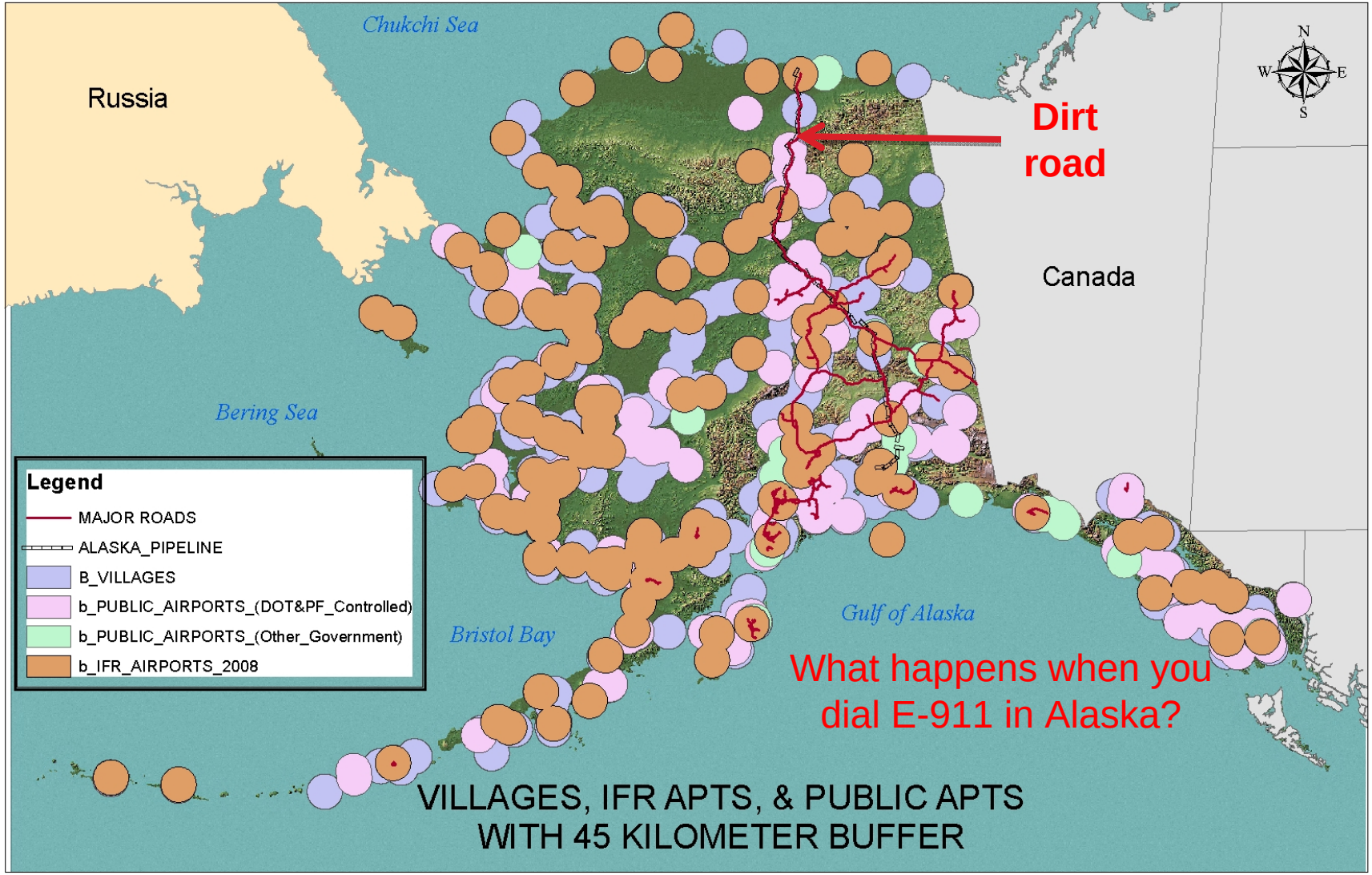
But what about Area 2 requirements in 2010?

ICAO Area 2 Requirements Compared with DTED Level 2

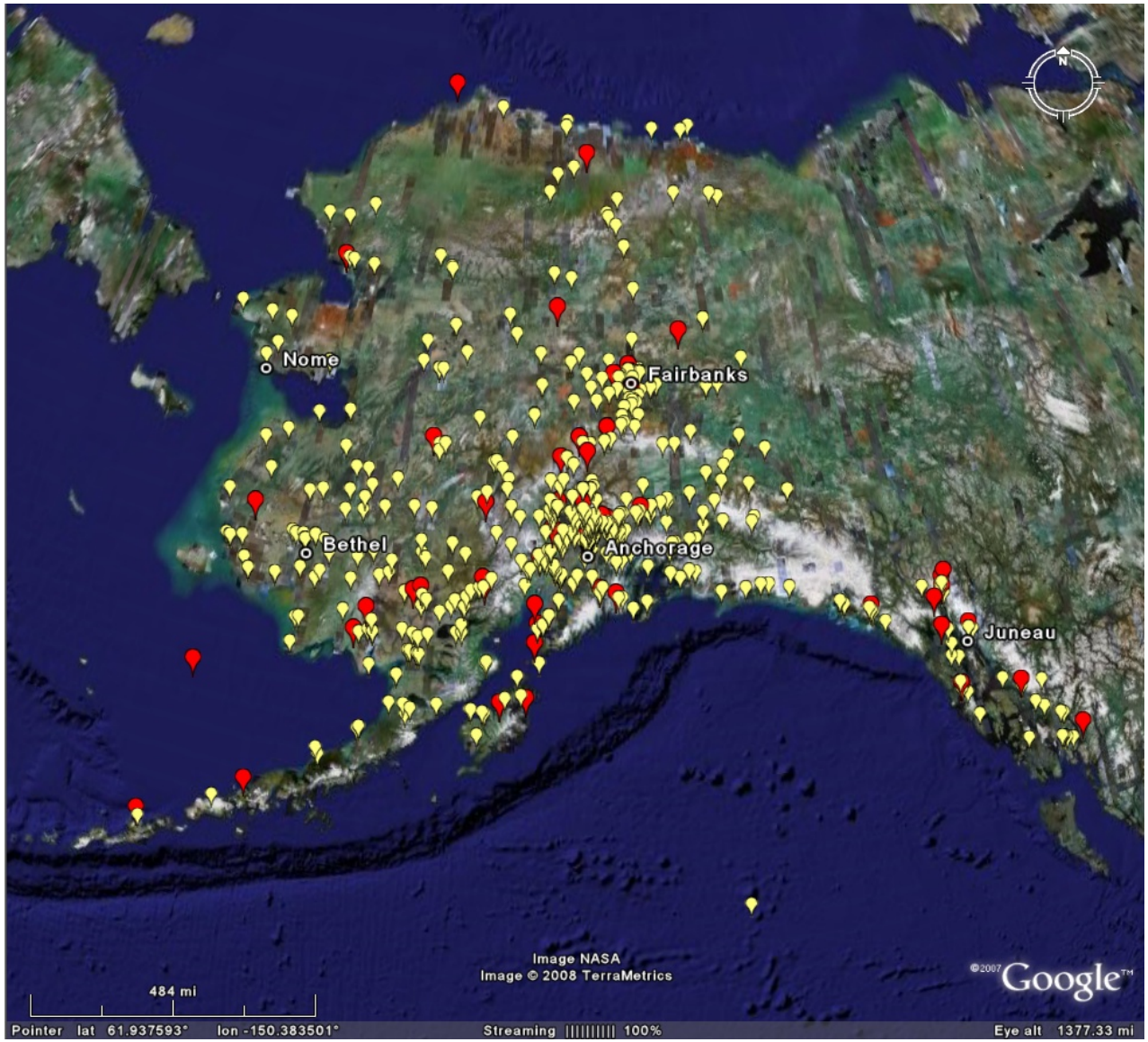
	ICAO Area 2 Standards	DTED Level 2
Post Spacing	1-arc-second (≈30 meters) latitude & longitude	1-arc-second (latitude) 2-4 arc-seconds (longitude)[1]
Vertical Accuracy (LE90)	3 meters	18 meters
Equivalent Contour Interval	6 meters (20 ft)	36 meters (118 ft)
Vertical Resolution	0.1 meter	1 meter
Horizontal Accuracy (CE90)	5 meters	23 meters
Confidence Level	90%	90%

[1] Note: DTED Level 2 variable post spacing north of 50° North Latitude

1,004 combined IFR and emergency sites



Fatal (red) & non-fatal accidents (2001-2005)



Vertical Accuracy Requirements

DEM User Groups	High-accuracy 10' and better contour accuracy (Airborne LiDAR)	Mid-accuracy 20' to 30' contour accuracy (Airborne IFSAR)	Low-accuracy 40' and worse contour accuracy (Satellite Sensors)
Alaska Aviation		20' contour accuracy ICAO Area 2 standard	200' contour accuracy ICAO Area 1 standard
Alaska DCCED	2' contour accuracy		
Alaska DGGS	2' & 10' contour accuracy		50' & 100' contour accuracy
Alaska DNR			40' contour accuracy
Alaska DOT	4' & 10' contour accuracy		
Alaska University Users	2' & 10' contour accuracy	30' contour accuracy	50' contour accuracy
BLM		20' contour accuracy	
DOD		20' contour accuracy	
NGA			50' contour accuracy
NOAA[8]	2' contour accuracy	20' contour accuracy	40' contour accuracy
NPS			40' contour accuracy
NRCS			40' contour accuracy
USFS		20' contour accuracy	
USGS	10' contour accuracy ("ideal")	20' contour accuracy ("preferred")	40' contour accuracy ("acceptable")

Vertical Accuracy of Airborne IFSAR Options

Competing Airborne IFSAR Systems	Slope: 0° to 10° (Accuracy$_z$ at 95% confidence level)	Slope: 10° to 20° (Accuracy$_z$ at 95% confidence level)	Slope: 20° to 30° (Accuracy$_z$ at 95% confidence level)
Intermap's STAR-3/4/5/6			
Type III DSM	6 m ≈33-ft contour accuracy	9 m ≈50-ft contour accuracy	12 m ≈66-ft contour accuracy
Type II DSM	1.8 m ≈10-ft contour accuracy	3 m ≈17-ft contour accuracy	4 m ≈22-ft contour accuracy
Type II DTM (untested, assumed equal to DSM)	1.8 m ≈10-ft contour accuracy	3 m ≈17-ft contour accuracy	4 m ≈22-ft contour accuracy
	Flat Terrain Yahoo County, MS	**Moderate Terrain Southern California**	**Rolling Terrain Southeast Asia**
Fugro EarthData's GeoSAR X-band DSM	1.8 m ≈10-ft contour accuracy	1.86 m ≈10-ft contour accuracy	8.78 m ≈49-ft contour accuracy
P-band DTM	≈10-ft contour accuracy	≈10-ft contour accuracy	≈49-ft contour accuracy
	P-band foliage penetration (10-20m typical) is slope and foliage dependent		

Vertical Accuracy of Satellite Options

Competing Satellite Sensor Systems with contour interval (CI) accuracy	Slope: 0° to 20° $Accuracy_z$ at 95% confidence level and equivalent CI	Slope: 20° to 40° $Accuracy_z$ at 95% confidence level and equivalent CI	Slope: >40° $Accuracy_z$ at 95% confidence level and equivalent CI
ASTER Global DEM	20m (110-ft CI)	Unavailable	Unavailable
GeoEye's IKONOS, 1-arc-sec w/o GCPs 0.2-arc-sec w/1 GCP per stereo model	24 m (132-ft CI) 16.7 m (92-ft CI)	Unavailable	Unavailable
Digital Globe's WorldView-1, w/o GCPs	8 m (44 ft CI)	Unavailable	Unavailable
Spot Image Corp's SPOT-5, w/o GCPs	11.9 m (66-ft CI)	21.4 m (118-ft CI)	35.7 m (197-ft CI)
ASRC's Cartosat-1 w/9 GCPs/scene	6-9 m (33-50 ft CI)	10-20 m (55-110 ft CI)	Unavailable
MDA's Radarsat-2, w/minimal GCPs (see mode explanations below)	**Slope: 0° to 20°**	**Slope: 20° to 40°**	**Slope: >40°**
— Multi-Look Fine (MLF) beam mode	0-10°: 8m (44-ft CI) 11-20°: 12m (66-ft CI)	21-30°: 15m (83-ft CI) 31-40°:17m (94-ft CI)	20m (110-ft CI)
— Ultra Fine (UF) beam mode	0-10°: 6m (33-ft CI) 11-20°: 8m (44-ft CI)	21-30°: 11m (61-ft CI) 31-40°: 12m (66-ft CI)	15m (83-ft CI)

ASTER GDEM now being evaluated but won't satisfy 20-ft CI need

Strengths/Weaknesses of Optical Imagery

- Neither day/night nor all-weather
- Photogrammetry produces both orthophotos and DEMs
  - DSMs produced by automated image correlation
  - DTMs produced by manual compilation, more expensive
- Difficult to accurately maps glaciers and mountains with perpetual snow cover.
- Airborne imagery: With good base/height ratio, DTM vertical accuracy comparable to 1-ft to 20-ft contours, but expensive
- Satellite imagery: Most options are DSMs only and not DTMs. Vertical accuracy comparable to 50-ft contours (very expensive, with lots of GCPs) to 200-ft contours (less expensive, w/o GCPs).

Strengths/Weaknesses of LiDAR

- Day/night, but <u>not</u> all-weather; must be cloud free
- Single laser pulses penetrate through or between trees
- Most accurate option for DTMs in dense forests and vegetation
- Most accurate elevation differences between DSM and DTM for forestry applications.
- Ideal for 1-ft to 2-ft contour accuracy requirements
- Can accurately map mountains with perpetual snow cover; tested in Greenland
- Impractical and unaffordable statewide, but NASA's EAARL may fly Alaska's major shorelines to satisfy topo/bathy needs.

Strengths/Weaknesses of IFSAR

- Both day/night and all-weather
- Flies at 35,000 to 40,000 feet AGL, perfect for GRAV-D
- Ortho-rectified radar images (ORI), plus DSMs and DTM, ideal for 10-ft to 20-ft contour accuracy
- Intermap produces DTMs by editing of DSM; Fugro EarthData produces DTMs from P-band IFSAR
- Intermap may have licensing issues; no Fugro issues
- Significantly less expensive than either airborne LiDAR or airborne imagery solutions
- Radarsat-2 has the least expensive option, but the DSM combined accuracy is equivalent to 83-ft contours
- Maps glaciers and mountains with perpetual snow cover

Airborne IFSAR Considerations

In addition to satisfying all statewide requirements, because their aircraft fly at altitudes between 35,000 and 40,000 feet, IFSAR aircraft could potentially be fitted to accommodate the National Geodetic Survey's GRAV-D sensor and operator in order to simultaneously collect gravity data for improving the geoid height model so desperately needed in Alaska.

•Intermap Technologies appears to have a competitive advantage by having more flexibility with a larger fleet of aircraft, and it has proven experience for large, successful projects in production of NEXTMap USA, NEXTMap Britain, and NEXTMap Europe.

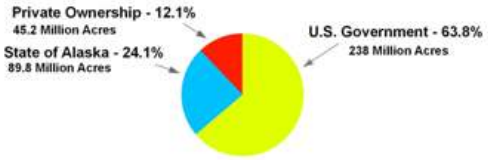
•Fugro EarthData appears to have a competitive advantage because of GeoSAR's X-band and P-band sensors that may be superior for accurate mapping of both the DSM and DTM in forested regions, and images the terrain with about 4x redundancy from multiple look directions to minimize shadow & layover.

Airborne IFSAR Conclusion

An IFSAR hybrid IFSAR solution should be considered in order to benefit from the advantages of both Intermap and Fugro EarthData. Discriminating factors should include:

- Comparative costs, including licensing
- Technical advantages of X-band and P-band for different areas
- Plans to minimize and mitigate artifacts from layover/shadow
- Past performance (satisfied clients?)
- Whether or not the IFSAR aircraft could simultaneously accommodate a NGS gravimeter and operator in order to also support the GRAV-D program by collecting gravity data along the same flight lines as the IFSAR data collection.

Who Owns/Manages Alaska?



Russian traders arrived in Alaska in the mid-1700's and established small, scattered trading posts and settlements. Alaska Natives (the Eskimo, Indian, and Aleut peoples) continued as the primary landowners during this period of Russian occupation. On October 18, 1867, Russia sold Alaska to the United States government. As a result, the federal government owned the Alaska Territory, approximately 373 million acres -about one-fifth the size of the rest of the U.S.

State of Alaska - 89.8 million acres

Under the terms of the Alaska Statehood Act of 1959, the federal government granted the new state 28% ownership of its total area. Approximately 103,350,000 acres were to be elected under three types of grants:

1) Community - 400,000 acres

2) National Forest Community - 400,000 acres

3) General - 102,550,000 acres

Additional territorial grants, for schools, university and mental health trust lands, totaling 1.2 million acres were confirmed with statehood.

All grants combined gave the State of Alaska approximately 105 million acres. To date, 89.9 million acres has been granted, with the balance expected to be granted by 2009.

ANCSA Native Corporation (Private) 39.3 million acres

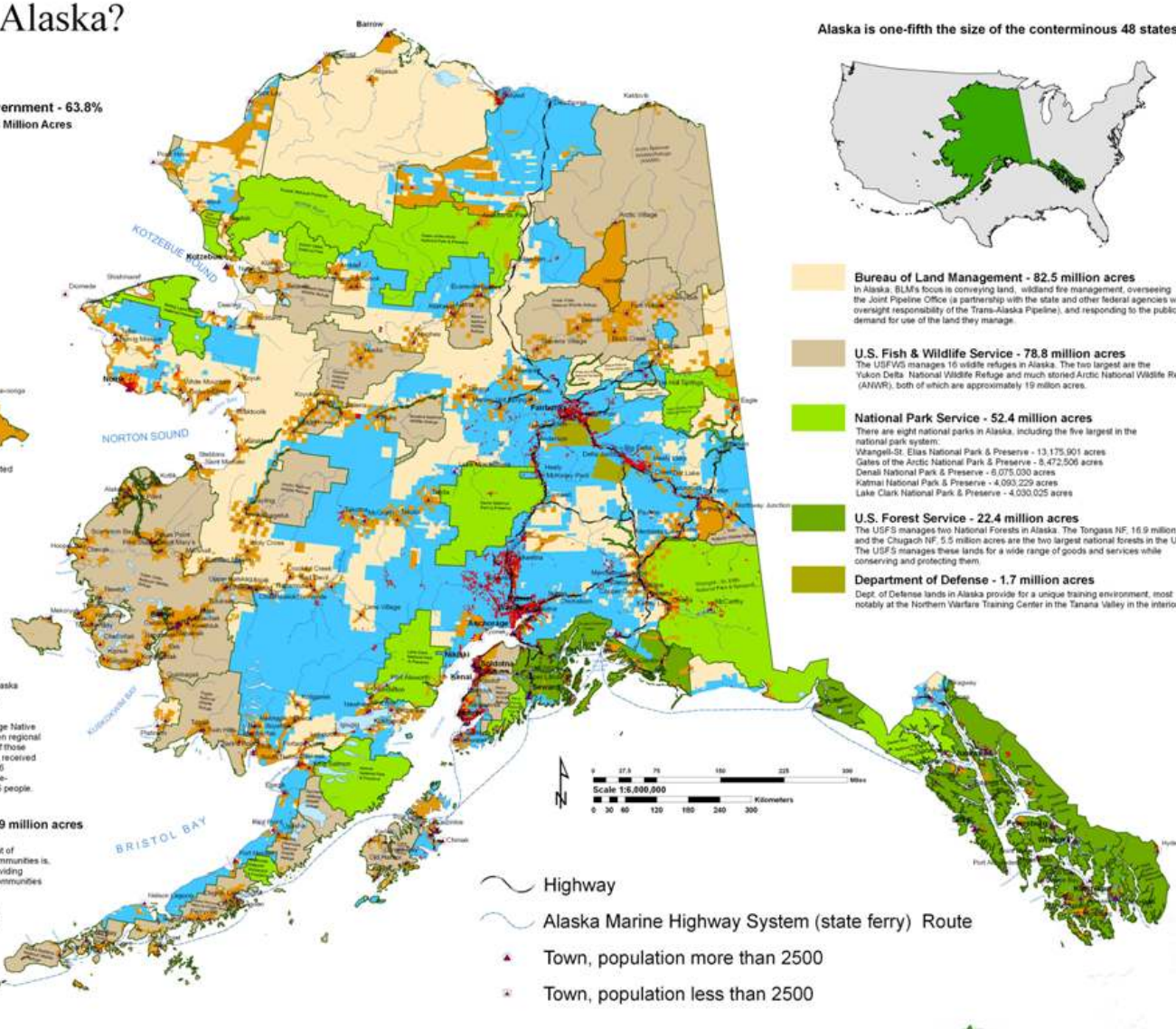
On December 18, 1971, P. L. 92-203, the Alaska Native Claims Settlement Act was signed into law. The purpose of ANCSA was to legislate the terms by which Alaska Natives could acquire title to their lands. This claim had been unresolved for more than 100 years since the United States purchased Alaska from Russia in 1867.

Native lands are private lands. ANCSA mandated the creation of regional and village Native corporations to manage 44 million acres and payment of one billion dollars. Thirteen regional corporations were created for the distribution of ANSCA land and money. Twelve of those shared in selection of 16 million acres, the thirteenth corporation, based in Seattle, received a cash settlement only. 224 village corporations, of 25 or more residents, shared 26 million acres. The remaining acres, which include historical sites and existing native-owned lands, went into a land pool to provide land to small villages of less than 25 people. To date, 39.3 million acres have been transfered to ANCSA corporations.

Non-ANCSA Private & Local Government - 5.9 million acres

Land in private ownership (other than Native land) comprises less than one percent of the total land in Alaska. Much of the best land for development around Alaska's communities is, or will be, privately owned. Private land development meets people's needs by providing places to live, work, shop and recreate. It also provides a tax base for cities and communities to help support public services.

Because local governments in Alaska have individual methods of transfering land into private ownership, land currently owned by them is grouped into this catagory.



Alaska is one-fifth the size of the conterminous 48 states.

Bureau of Land Management - 82.5 million acres

In Alaska, BLM's focus is conveying land, wildland fire management, overseeing the Joint Pipeline Office (a partnership with the state and other federal agencies with oversight responsibility of the Trans-Alaska Pipeline), and responding to the public demand for use of the land they manage.

U.S. Fish & Wildlife Service - 78.8 million acres

The USFWS manages 16 wildlife refuges in Alaska. The two largest are the Yukon Delta National Wildlife Refuge and much storied Arctic National Wildlife Refuge (ANWR), both of which are approximately 19 million acres.

National Park Service - 52.4 million acres

There are eight national parks in Alaska, including the five largest in the national park system:
Wrangell-St. Elias National Park & Preserve - 13,175,901 acres
Gates of the Arctic National Park & Preserve - 8,472,506 acres
Denali National Park & Preserve - 6,075,030 acres
Katmai National Park & Preserve - 4,093,229 acres
Lake Clark National Park & Preserve - 4,030,025 acres

U.S. Forest Service - 22.4 million acres

The USFS manages two National Forests in Alaska: The Tongass NF, 16.9 million acres, and the Chugach NF, 5.5 million acres are the two largest national forests in the U.S. The USFS manages these lands for a wide range of goods and services while conserving and protecting them.

Department of Defense - 1.7 million acres

Dept. of Defense lands in Alaska provide for a unique training environment, most notably at the Northern Warfare Training Center in the Tanana Valley in the interior

Maps produced by the
Alaska Dept of Natural Resources
Division of Forestry

Alaska Upland Land Ownership/Management (Statewide total ≈ 1.8 million Km^2)

Whose problem is it?

All of us; we need funding partners

	Million acres	Km^2	% of total
State of Alaska	89.8	363,408	24.1
BLM	82.5	333,866	22.1
USF&WS	78.8	318,892	21.1
NPS	52.4	212,055	14.1
ANCSA	39.3	159,041	10.5
USFS	22.4	90,650	6.0
Other private	5.9	23,876	1.6
DoD	1.7	6,880	0.5
TOTALS	372.8	1,508,668	100.0

Met with NDOP and NDEP in August

An additional 65 million acres of Tide and Submerged Lands are mapped for offshore drilling activities and sea ice monitoring.

Consensus points (agree or disagree?)

We have no time to waste

- ICAO Area 1 Requirements: 11/20/2008
- ICAO Area 2 Requirements: 11/20/2010
- Other statewide user requirements: Immediate
- Alaska's mapping needs have been neglected for 50 years; unmet needs in Alaska are dire, especially aviation safety

We must remain true to Alaska's requirements

- 20' contour accuracy or better
- Both DSM and DTM, especially mountain peaks, ridgelines and hydrology
- Technology that overcomes adverse weather conditions
- Technology that maps snow-capped mountains & glaciers
- Technology that is cost-effective

We must find timely, cost-effective solution

- Only airborne mapping options can satisfy AK's technical and accuracy requirements
- Airborne IFSAR costs are significantly less than airborne LiDAR or photogrammetry
- Multiple contracting options are available to obtain the most cost-effective solution for timely delivery of quality products
- Need both federal and state funding

Agree or disagree on other points?

We have time to reach consensus elsewhere

- Data acquisition and post-processing can proceed if we choose ellipsoid heights and Alaska Albers, for example, knowing that NED will be provided as geographic coordinates in ESRI grid format
- Other issues can be resolved while data are being acquired and processed

What other requirements should be satisfied? How? By whom?

- Will GINA serve multiple datasets to the public?
- Will GINA provide orthometric heights that change with new geoid models?
- Will GINA provide GeoTiff and/or other file formats
- Who will perform hydro-enforcement of DTM? How? Who pays?
- Who will filter DTM so roads are smooth on orthophotos? How? Who pays?

We must find cost-effective solution

- Answers to these questions may depend on available funds and contract costs for data acquisition & processing
- If available funds are inadequate to pay for everything as part of major contract, get data acquired and DSM/DTM delivered ASAP; then determine if those responsible for land management pay for hydro-enforcement, etc. if needed for their areas of responsibility.

USGS Task Order: Alaska DEM Initiative – Phase II

Alaska DEM Funding & Implementation Plan

- Executive Summary
- Agency Executive Leadership Communications, incl. DOI (USGS, BLM, NPS, F&WS, BIA); DOD (NGA); DHS; NGS; FAA; USDA (USFS, NRCS, FSA); State of Alaska
- Initiative Plan, incl. FGDC coordination and Agency Executive Leadership coordination
- Brief 2/27/09 at Alaska Mapping Conference

Need Funding Partners to solve a common need

Alaska DEM, “shovel-ready”

Obama eyes 'shovel-ready' fixes in a long recovery

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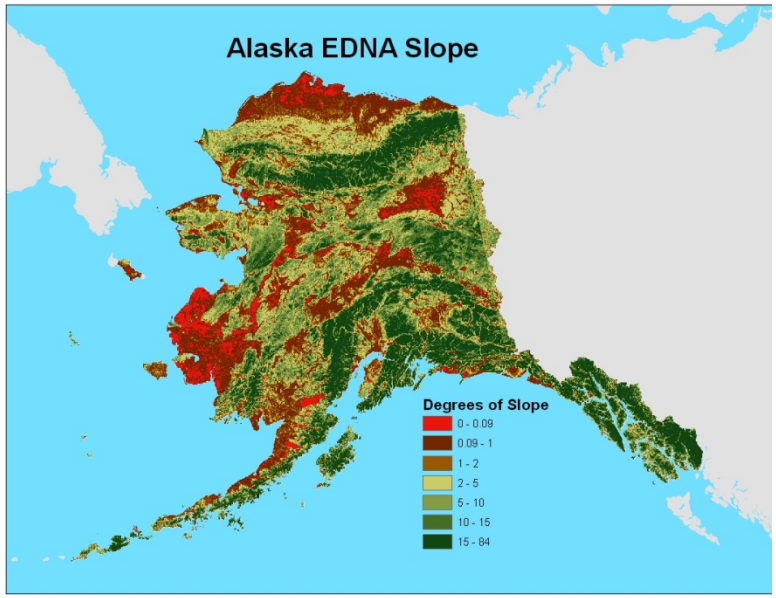
By Fredreka Schouten, USA TODAY

WASHINGTON — President-elect Barack Obama said Sunday that the nation's economic troubles likely will deepen, but he promised to deliver a vast government spending program to spur growth.

"Things are going to get worse before they get better," Obama said on NBC's *Meet the Press*.