Geophysical and Geodetic Analysis of Airborne Gravity Data from GRAV-D in Alaska (Gravity for the Redefinition of the American Vertical Datum)

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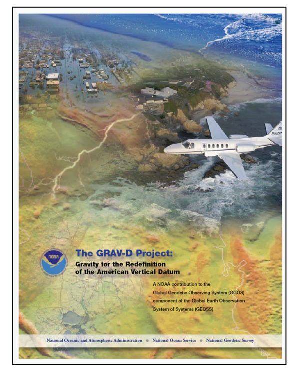
1. What is GRAV-D?



Goal: To Re-define the US Vertical Datum by creating a new gravimetric geoid

Official National Geodetic Survey Policy with Congressional Funding in 2010

Two Major Program Elements:
1. Airborne Gravity "Snapshot" for Baseline Gravity of U.S. by 2018
2. Long Term Monitoring of Temporal Changes

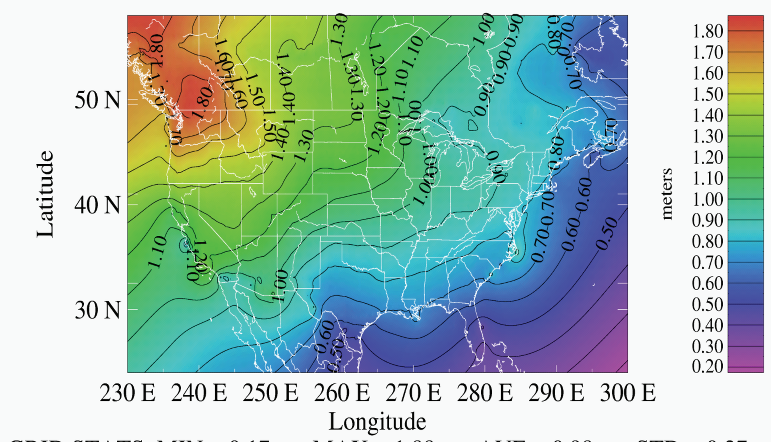
2. Importance of Improving the American Verical Datum

The current vertical datum- NAVD88- does not represent mean sea level (see bottom left).

It is NGS' mission to define and maintain a spatial reference system for the U.S. Part of this mission is to provide access to heights useful for measuring water flow (particularly for flood hazard estimation) and for construction/transportation projects. Based on current errors and requirements in the era of GPS, a new datum with 1-2 cm accuracy is needed.

Using a gravimetric geoid is ideal (the geoid is the surface of the gravity field that most closely approximates mean sea level). But, new and extensive gravity data must be collected in order to unify the current data holdings. Airborne gravity data can easily extend over the littoral gap between terrestrial and marine (ship track) measuements, providing a consistent and seamless dataset across the entire U.S. (see bottom right). Also, airborne data provide power to the geoid at intermediate wavelengths between GRACE and surface gravity measurements.

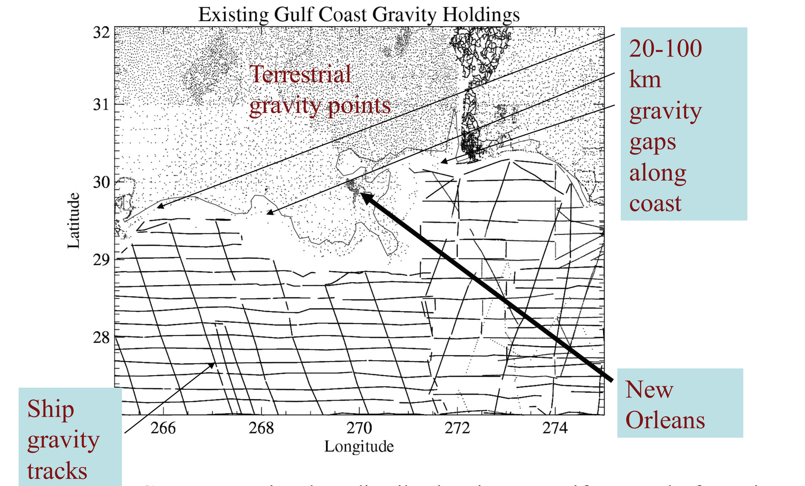
Error in NAVD88 compared to a datum derived from GRACE



GRID STATS: MIN = 0.17 m MAX = 1.88 m AVE = 0.98 m STD = 0.37

White outline is the coastline and states. Black contours are error in meters.

Existing Gulf Coast Gravity Holdings



Current gravity data distribution is non-uniform and of varying quality, particularly with large data gaps in the littoral regions.

3. Data Collection Priorities and Progress

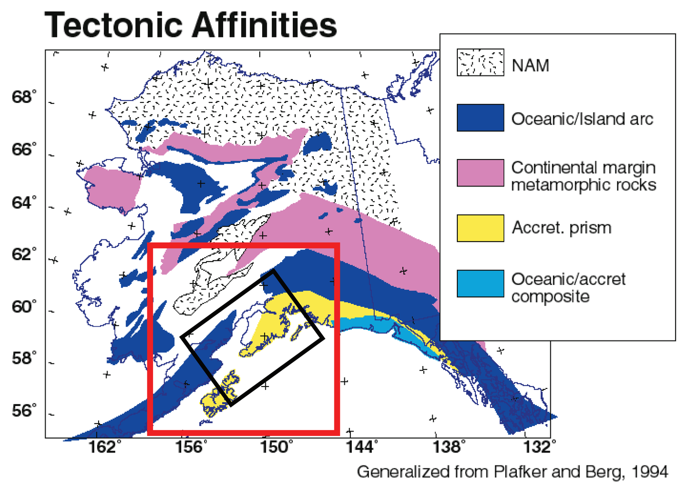
Airborne surveys are planned to cover all states and the U.S. holdings by 2018, with full funding.

Priorities: 1. Alaska, 2. Great Lakes Region, 3. Finish Gulf Coast, 4. Hawaii, 5. East Coast, 6. West Coast, 7. Interior Continental U.S. & Holdings

Data Collection Finished (see right): Western Gulf of Mexico (2008-2009), Puerto Rico and the Virgin Islands (2009), Alaska (2008, 2009).

Data processing for precise GPS and gravity is an on-going area of development. Products will start to be available in late 2010.

4. Anchorage, AK Setting for 2008 Airborne Gravity Survey

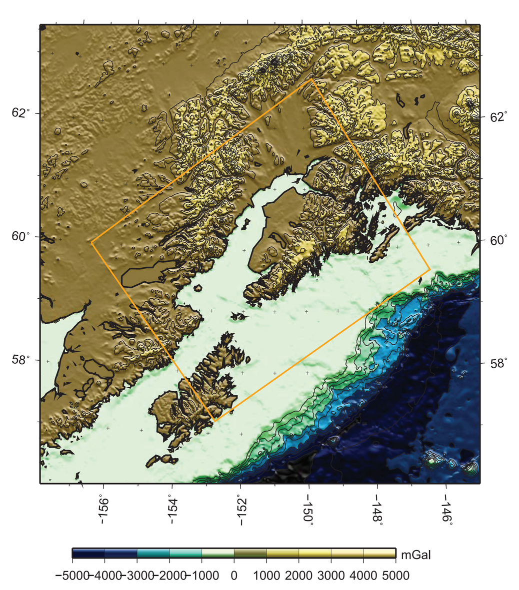


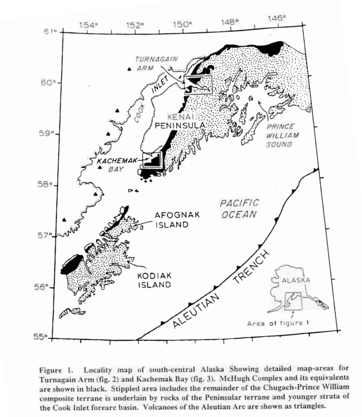
Tectonic Setting of Alaska from Saltus, et al. (1999).

Modified: red box is the location of all other figures and black box is the area surveyed in July 2008 with airborne gravity for the GRAV-D project.

Bathymetry derived from ship depth measurements and ERS-1/Geosat satellite marine gravity (Smith and Sandwell, 1997) and topography from GTOPO30 (see References for download locations of these data sets). Orange box marks the outline of the 2008 GRAV-D airborne survey.

Topography/Bathymetry for the Anchorage Area





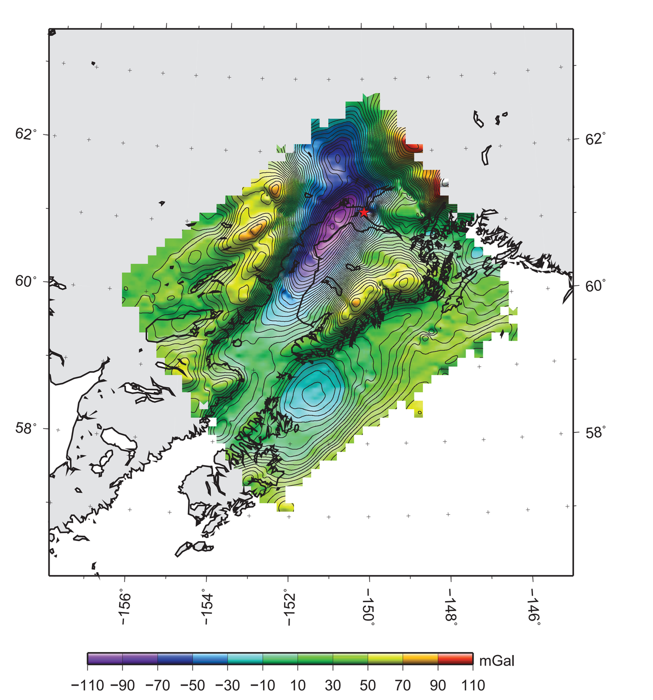
Geology of Kenai Peninsula and Cook Inlet area (Bradley, et al., 1997). Note the old accretionary prism (in gray and black) and currently active volcanic arc (small black triangles).

5. Evaluating Gravity Products: Anomaly vs. Disturbance

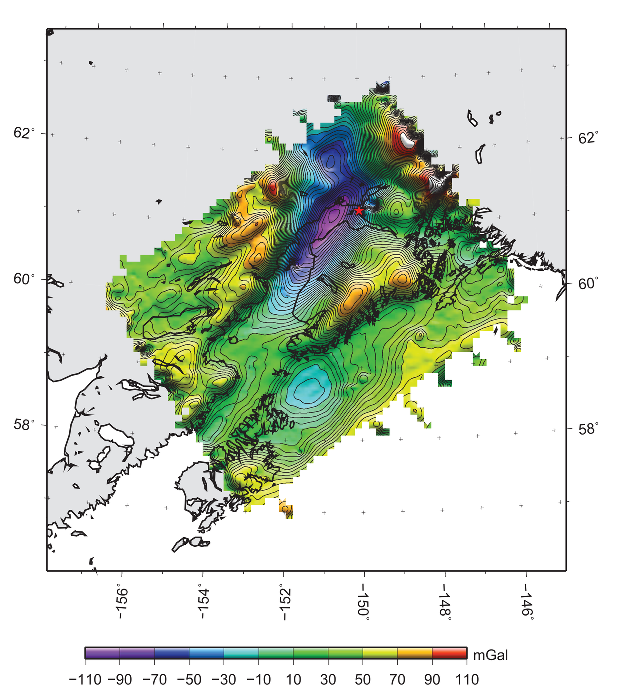
The AeroGrav software from Micro-G LaCoste calculates free-air anomalies (FAA) using orthometric heights in the processing calculations (right).

This product is not as useful for geodetic applications since it removes the complex gravity effect of the "geoid" used. Although, it is useful for geophysical analyses.

Free-Air Gravity Anomaly Processed with AeroGrav



Free-Air Gravity Disturbance Processed with NGS Software



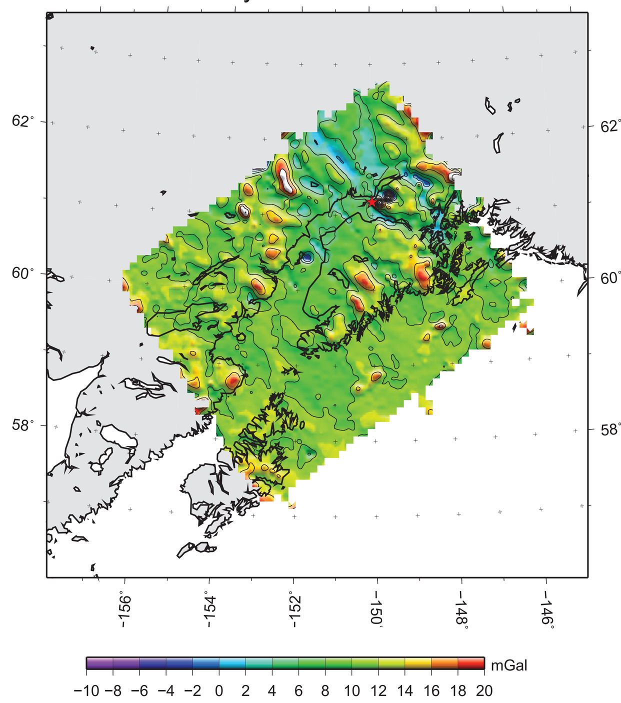
Instead, a free-air gravity disturbance (FAD) referenced to the WGS-84 ellipsoid (left)- processed with in-house NGS software- retains the gravity effect of the geoid. This data more closely matches EGM08 (see table/figures below) and is useful for calculations to produce a new geoid model.

Data Set(s)	Mean (mGal)	RMS (mGal)
FAA AeroGrav	18.36	24.14
FAD NGS	29.85	30.21
EGM08	26.91	29.37
Diff FAA - FAD	-11.49	15.69
Diff FAA - EGM08	-8.45	16.24
Diff FAD - EGM08	2.98	19.48

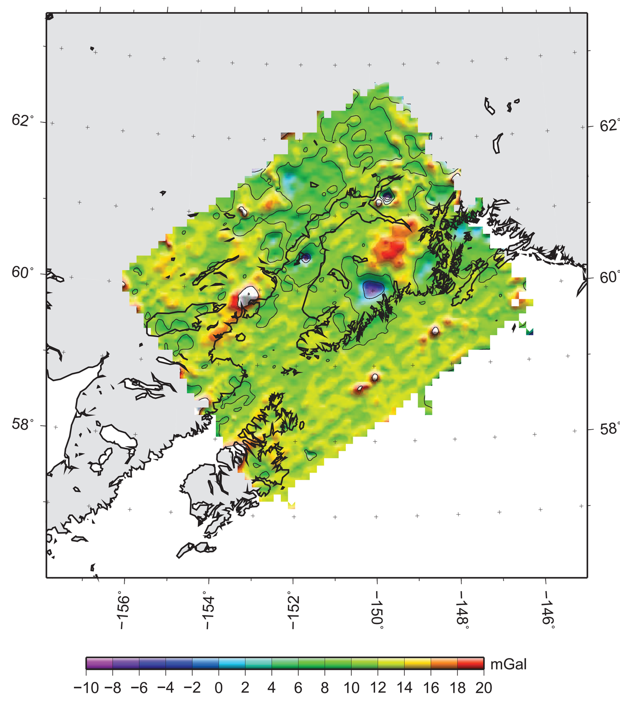
The difference between the FAA and FAD is primarily due to filtering and using ellipsoidal heights (gravity disturbance) rather than orthometric heights (gravity anomaly) during the calculation of corrections (*See session G54A talks 04-06 for more information*).

The ideal gravity product for producing a gravimetric geoid is a full-field gravity measurement that does not use the Earth's shape in its processing (no ellipsoid or geoid as a reference surface).

Free-Air Anomaly Minus Free-Air Disturbance



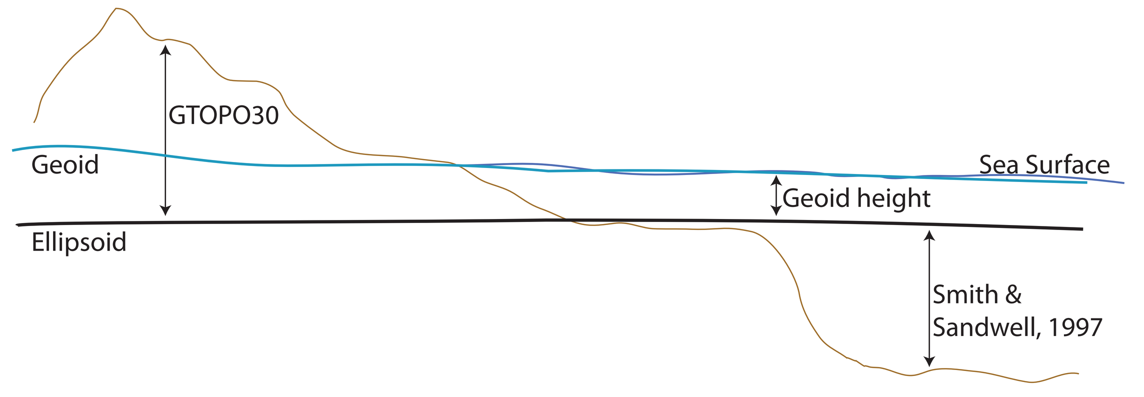
Free-Air Disturbance Minus EGM08



The differences between the FAD and EGM08 appear to be mostly aircraft noise (small features) and bias along tracks. The remaining differences are either errors in the data included in EGM08 or real changes in the gravity field. For instance, the largest FAD-EGM08 differences are located in the accretionary prism and volcanic arc, where we would expect geologic activity (see Geology of Kenai in center).

6. Implications for Bouguer Gravity Calculations

A full Bouguer correction (which includes the terrain correction) may be calculated with either free-air gravity product. However, care must be taken when defining the relationships between the processing datum and land/water surfaces. For instance (see below), when using a free-air disturbance, treating the ellipsoid as sea level neglects to correct for the real mass of water above or below the ellipsoid (as indicated by geoid height) and will produce significant error in Bouguer results- both offshore and near-shore.



7. Discussion/Conclusions

1. If given the choice of gravity product to use in creating a gravimetric geoid, choose the product with the simplest datum. E.g. full-field is better than disturbances, which are both better than anomalies. Choosing products this way simplifies the geoid calculation by embedding into the data the fewest assumptions about the shape of Earth.

2. Free-air gravity disturbances (FAD) calculated with NGS software more closely match EGM08 than free-air anomalies (FAA) from Micro-g LaCoste's AeroGrav software. Differences between the FAD and EGM08 clearly show aircraft noise, as well as real gravity changes/errors in EGM08's underlying data. Signals most likely to be real are the differences on the Kenai Peninsula accretionary prism and in the volcanic arc.

3.Care must be taken with datums when geophysicists perform free-air and Bouguer gravity corrections. Inappropriate use of orthometric heights can lead to large errors. Also, for the Bouguer correction, datums much match between the airborne gravity product and the topographic/bathymetric/geoid height products. Geodesist should be wary of gravity products that do not explicitly state how datums were handled.

References

Bradley, D.C., T.M. Kusky, S.M. Karl, and P.J. Haeussler. (1997) "Field Guide to the Mesozoic Accretionary Complex Along Turnagain Arm and Kachemak Bay, South-Central Alaska." Alaska Geological Society. Available: http://alaska.usgs.gov/staff/geology/bradley/pubs/1997_Bradley_Kenai_Penin_AGS_field_trip.pdf

Saltus, R.W., P.L. Hill, G.G. Connard, T.L Hudson, and A. Barnett. (1999) "Building a Magnetic View of Alaska." U.S. Geological Survey Open-File Report 99-0418. Available: http://pubs.usgs.gov/of/1999/ofr-99-0418/

Smith, W.F. and D.T. Sandwell. (1997) "Global Sea Floor Topography from Satellite Altimetry and Ship Depth Soundings." *Science* **277**, 1956-1962. Data available: http://www.mathworks.com/support/tech-notes/2100/2101.html; ftp://topex.ucsd.edu/pub/global_topo_2min/; http://edcwww.cr.usgs.gov/landdaac/gtopo30/gtopo30.html