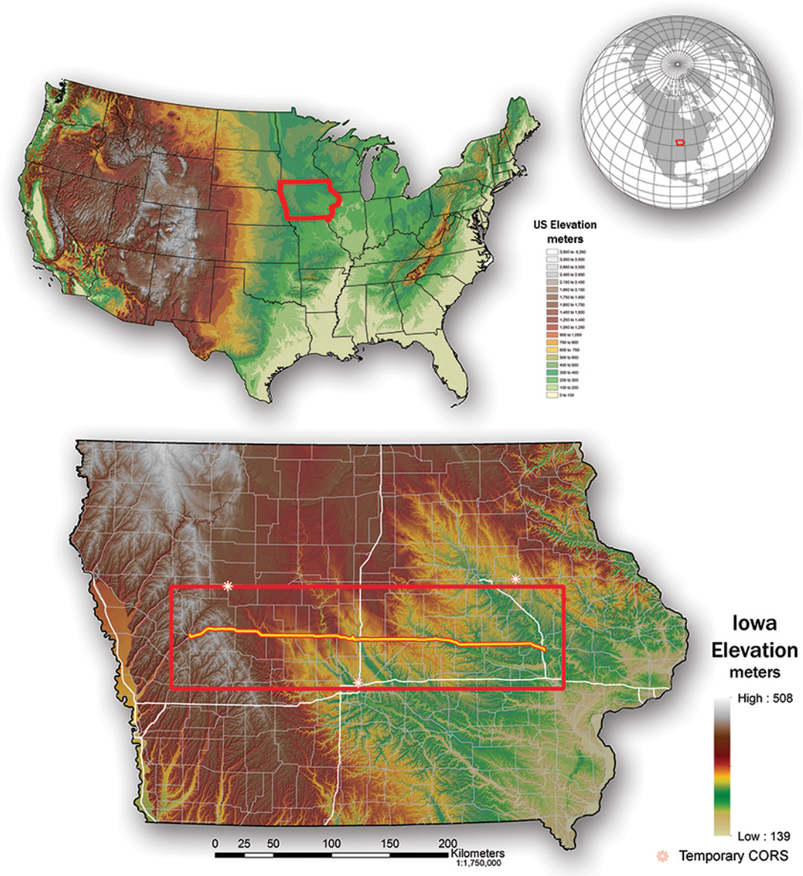
NOAA's National Geodetic Survey

GSVS14

Geoid Slope Validation Survey



Who is NOAA/NGS?

The National Oceanic and Atmospheric Administration (NOAA) is the nation's oldest scientific agency dating back to 1807 when Thomas Jefferson created the Survey of the Coast. This agency was created to assist the United States of America to help increase commerce by providing maps of the land, shore and waterways to assist shipping, the main form of commerce, and avoid ship wrecks. NOAA's mission is Science, Service and Stewardship, to understand and predict changes in climate, weather, oceans, and coasts; to share that knowledge and information with others; to conserve and manage coastal and marine ecosystems and resources.

The National Geodetic Survey (NGS) is a program office within NOAA's National Ocean Service. NGS defines the position and height framework for the US and all its territories by developing the official US datums, and geoid models used for positioning. NGS' mission is to define, maintain and provide access to the National Spatial Reference System (NSRS) to meet our nation's economic, social, and environmental needs. One critical component of the NSRS is the determination of "height" --specifically ellipsoid height, orthometric height and dynamic height -- of any point in the United States or its territories. These surveys will greatly assist NGS in providing more accurate geoid models for determining or computing heights.

Validating the Geoid

The purpose of the Geoid Slope Validation Surveys is to confirm that using aerial gravity data aquired by the Gravity for the Redefinition of the American Vertical Datum (GRAV-D) will provide a regional 1 cm differential geoid accuracy. Three surveys are planned, each providing analysis over a characteristically unique region. In 2011 NGS performed GSVS11 in Texas which confirmed that a 1 cm geoid could be created in a flat and gravimetrically uncomplicated region. The 2014 survey was conducted in Iowa to evaluate a more complicated gravimetric region with more topographic variation than GSVS11. Iowa was chosen particularly due to the gravity anomaly caused by the Midcontinental Rift. You can see the rift as the primary feature in the maps below.

The GSVS' are composed of several different surveying methodologies that include GPS, digital leveling, astronomically observed deflection of the vertical (DOV) and both terrestrial and airborne gravity surveys. The objective of performing these surveys is to compare the geoid slope from co-located (temporally and spatially) GPS, leveling, DOV and terrestrial gravity data to the geoid slope derived from a gravimetric geoid created using the airborne gravity data. NGS will conduct at least three surveys of varying topographical regions (GSVS11 flat, GSVS14 moderate, GSVS16/17 rugged).

Orthometric Height (H) - Generally known as elevation. The distance along the plumb line from the geoid to the point of interest.

Ellipsoid Height (h) - The distance along the ellipsoidal normal from some chosen ellipsoid to the point of interest.

Geoid Undulation (N) - The distance along the ellipsoidal normal from some chosen ellipsoid to the geoid.

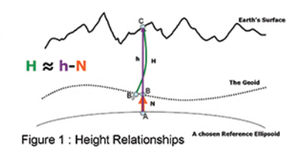


Figure 1 : Height Relationships

The Geoid

Two models are generally used to generalize the Earth's shape, the ellipsoid and the geoid. Both models are used in measuring and describing geographic locations vertically. The geopotential (potential of gravity) is also a function of the Earth's masses, but varies by $1/d$ instead of $1/d^2$ (where d is the distant between masses). A surface of constant geopotential is an equipotential surface. The optimal equipotential surface (or datum) is then selected to be the geoid -- that being the on best approximating global mean sea level. Figure 2 depicts the infinite equipotential surfaces (of which just one is the geoid) surrounding the Earth. The lines that are perpendicular to the geoid and all other equipotential surface are called plumb lines, and represent the local direction of the gravity vector. Almost every geodetic measurement depends in a fundamental way on the Earth's gravity field. Below is a map of the current US gravimetric geoid model for Iowa, USGG2012.

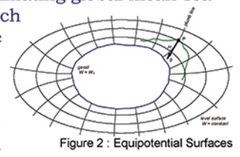


Figure 2 : Equipotential Surfaces

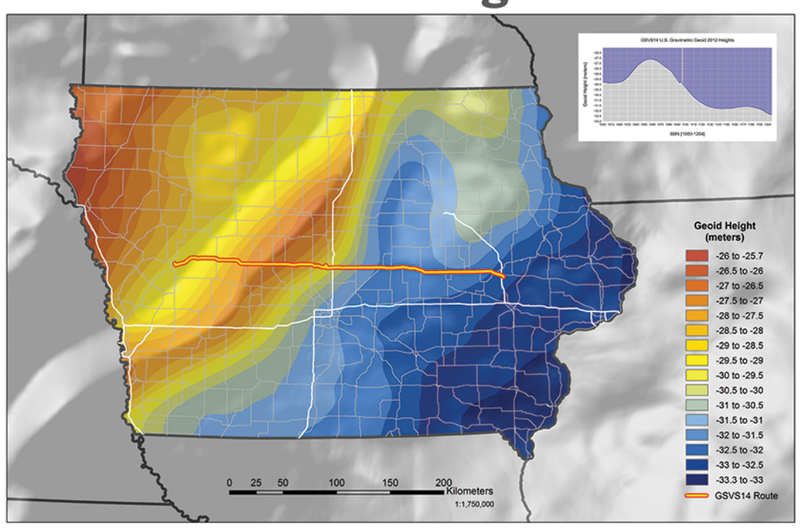
Deflection of the Vertical

The deflection of the vertical (DOV) is the departure of a plumb bob's actual pointing from the ellipsoidal normal direction. These quantities are typically a few arc-seconds, but can reach an arc-minute of departure. Deflections are used to relate the orientation of a locally leveled instrument such as a theodolite, to a spatial reference system. The current companion DOV model to the gravimetric geoid USGG2012 is the USDOV2012 which is comprised of both north-south (Meridian component, designated as "Xi") and east-west components (Prime vertical component, designated as "Eta"). The map below is the DOV magnitude which is a combination of the two components Eta and Xi by taking the square root of the sum of the squares. The DOV magnitude is the slope of the gravity equipotential surface at the topographic surface and is closely related to the slope of the geoid, but differs because the plumb lines are curved.

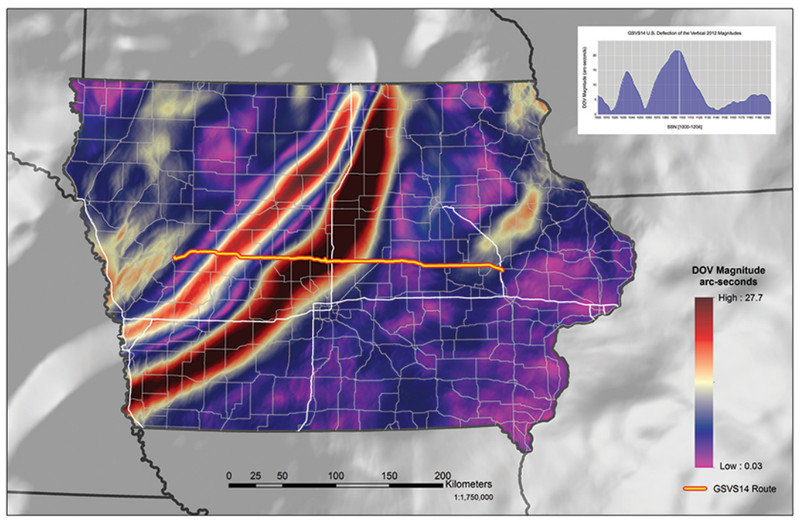
Gravity

Gravity is the combination of gravitational forces between masses and centrifugal forces caused by the Earth's roatation. According to Newton's law of gravitation two points with masses m1 and m2 separated by a distance d, attract each other with a force $F = G[(m1*m2)/d^2]$ where G is Newton's gravitational constant. Not only is gravity influenced by the distance between masses as described above, it is also influenced by the density of the masses. There are also centrifugal forces caused by the Earth's rotation influencing the observed gravity. The device measuring gravity observes all of these forces when collecting the gravity observations and it is the job of geodesists and geophysicists to derive local gravity values from the observed gravity. In order to view the gravity distribution over a local area there is a need to eliminate the global gravitational forces from the observed values which is done by calculating the free-air gravity disturbance. The free-air gravity disturbance provides the local gravity distributions based on topography and density variation as can be seen by the gravity map below.

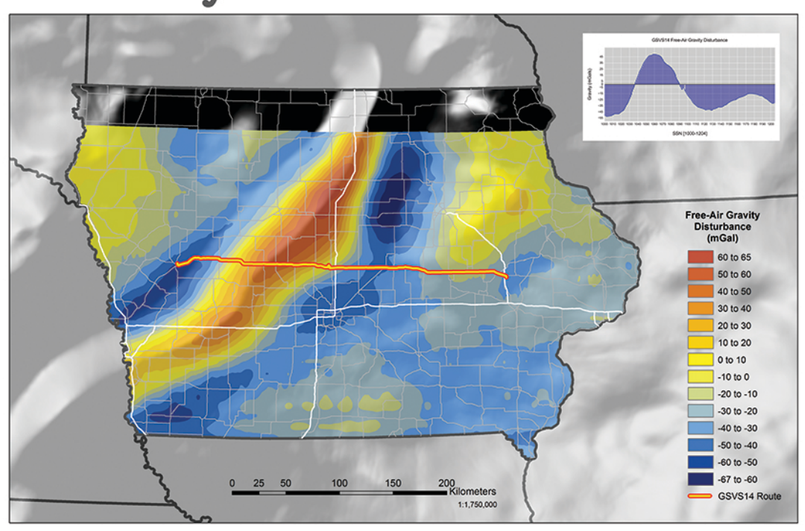
Geoid Height

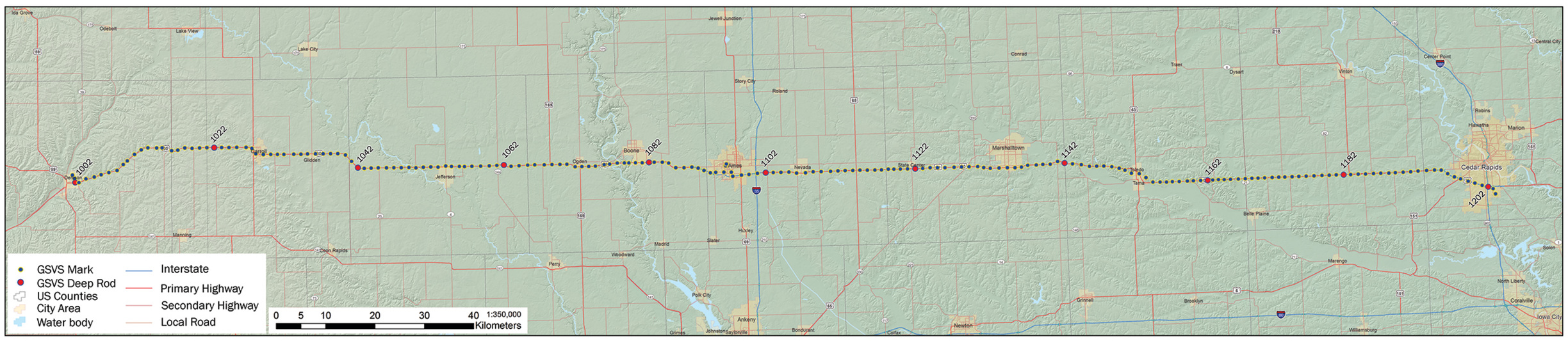


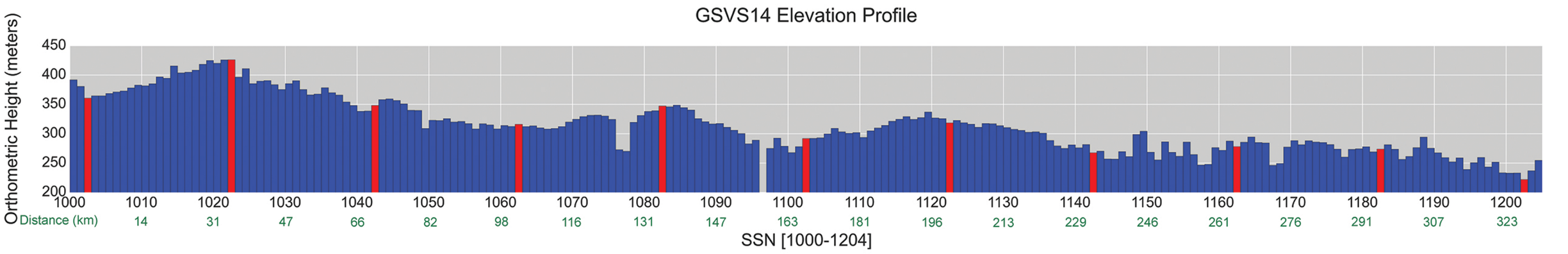
Deflection of the Vertical



Gravity Free-Air Disturbance







National Geodetic Survey
National Ocean Service
National Oceanic and Atmospheric Administration
United States Department of Commerce

By: Brian Shaw
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Data Sources: NOAA, USGS, U.S. Census, Esri
Datum: North American Datum of 1983 (2011)
Projection: USA Contiguous Lambert Conformal Conic