

How NOAA's GRAV-D Project Impacts and Contributes to NOAA Science

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In the 2010 NOAA Annual Guidance Memorandum (AGM), Dr. Lubchenco provided her vision of NOAA's Science, Stewardship and Service. The term "NOAA Science" is being interpreted broadly by various audiences. However, it is clear from the AGM that NOAA Science should be considered as the application of scientific excellence toward understanding of the Earth's environment in order to provide the best information possible to both the public and policy makers.

The National Ocean Service (NOS) conducts, sponsors, and facilitates science, and disseminates results in order to address societal and environmental needs. Science in NOS involves observation, measurement, analysis, and experimentation to describe, explain, track, and forecast natural and social phenomena. Within NOS, NOAA's National Geodetic Survey (NGS) has a federal mandate to provide accurate positioning, including heights, to all federal non-military mapping activities in the USA. In 2007, NOAA's National Geodetic Survey (NGS) embarked on the GRAV-D Project (Gravity for the Redefinition of the American Vertical Datum). This project was one of the most ambitious in the history of the agency, comprising no less than a complete survey of the gravity field over the USA and its territories, and a commitment to tracking decadal-scale changes to the gravity field. This undertaking was driven by the fundamental connection between Earth's gravity field and the very definition of "height" itself. The specific goal of GRAV-D is therefore to model and monitor Earth's geoid (a surface of the gravity field, very closely related to global mean sea level) to serve as a zero reference surface for all heights in the nation. Accurate heights are critical to many scientific endeavors, but particularly to understanding and protecting low-lying coastal ecosystems. At the completion of this project, NGS will be able to execute its mission with substantial improvements to both accuracy and efficiency. The benefits to the nation will be immense. A January 2009 socio-economic benefits study provided preliminary estimates for the value of the planned GRAV-D project. The benefits to the nation from completing GRAV-D are estimated to be \$4.8 billion over 15 years, including \$2.2 billion in avoidance costs from improved floodplain management.

It is also important to consider the AGM in order to understand how GRAV-D impacts and contributes to NOAA Science specifically. The application of NOAA Science has been prioritized in the AGM into five Strategic Priorities for 2010, *all of which* are impacted, and specifically improved, through the execution of NOAA's GRAV-D Project. In their AGM order, each is addressed below.

Enhance NOAA's climate services and support the establishment of a National Climate Service

Summary: *Climate impacts water, from sea level to local water tables, but these all have a definable gravity signature, which may be detectable through the GRAV-D project.*

The GRAV-D project has a decadal-scale gravity monitoring component, which is directly related to two components of climate driven changes to sea level. First, the GRAV-D project is truly about heights (by knowing gravity) and through the determination of accurate topographic heights at tide gages around North America, an understanding of local sea level changes will finally be possible.

Second, the primary shape of the ocean's surface is driven by Earth's gravity field, with tides and currents having almost two orders of magnitude less impact. As such, changes to the sea surface are directly linked to changes to the gravity field. As NGS monitors changes to the gravity field, these changes will reflect sea level change.

Furthermore, climate change will impact more than sea level. For instance, changes to water tables have been seen through their small, but measurable changes to the local gravity field. Therefore basin-scale changes to freshwater resources are potentially detectable through the monitoring aspect of GRAV-D. This data could be used to analyze both the climate driven impacts of the change and its long term implications.

Support Comprehensive Coastal and Marine Spatial Planning

Summary: *Marine Spatial Planning requires accurate positioning, including heights, which are the direct goal of the GRAV-D project.*

Effective Coastal and Marine Spatial Planning is reliant upon having an accurate geodetic and tidal datum reference system in place to provide an accurate framework to which all coastal and ocean uses and science can be assessed and planned.

The gravimetric geoid in particular will extend (and be extensively tested) in the littoral environment. Understanding the transitional factors involved in the "spatial" component of storm surge, for example, from offshore to onshore means that the spatial environment will be defined in a consistent way for both maritime and terrestrial regions.

Ensure the Sustainability of Marine Fisheries

Summary: *Building sustainable fisheries requires knowledge of the oceanic nutrient transport system, which is itself dependent upon good knowledge of ocean circulation patterns, which are derivable from GRAV-D products.*

While the GRAV-D project does not directly contribute to sustainable fisheries on its own, it will provide two critical pieces of information necessary to understanding the flow of fertilizers and nutrients as they impact fisheries.

First, accurate and consistent heights around the country, effectively replacing the multiple stream gage and river datums, will allow for more accurate agricultural run-off modeling, so that impacts of that run-off can be better understood as they reach the oceans.

Second, a gravimetric geoid over the oceanic regions of the United States and its territories will be provided. Such a well defined surface, when combined with sea surface height measurements, as taken by satellite altimeters such as JASON, allow for the determination of dynamic ocean topography, DOT (sometimes called sea surface topography).

Having accurate knowledge of DOT is directly related to knowledge of geostrophic ocean circulation patterns. As a specific example, an accurate geoid model (from GRAV-D) will lead to better DOT over the Gulf Stream, which will directly allow the quantification of both the width, direction and velocity of the Gulf Stream itself.

And the knowledge of such circulation patterns will obviously have a positive impact on modeling ocean nutrient transport.

Strengthen Arctic Science and Service

Summary: *Due to the significant lack of good geospatial data in the region, the highest priority area for GRAV-D is Alaska, where GRAV-D will allow for the determination of accurate heights (often off by hundreds of meters), the consistent determination of heights between airports (the primary form of transportation in Alaska), and the monitoring of glacial melting.*

In the GRAV-D plan, portions of Alaska, where virtually no geodetic control or gravity data exist and that are at high risk from the impacts of climate change, were given the highest priority. Priority was also given to at-risk coastal areas, island regions, and other areas of the country which have an urgent and pressing need for better protection against inundation from storms, flooding, and/or sea level rise. In general, through the GRAV-D plan, the coastal areas of the U.S., starting with Alaska and including the Aleutians, will be covered first with later expansion to inland regions.

The completion of GRAV-D in Alaska will strengthen Arctic Science and Service in many ways. Most significantly will be through providing a vertical reference framework, long needed in Alaska, to support Alaska's Statewide Digital Mapping Initiative – maps of Alaska can be notoriously inaccurate, with entire mountains misplaced by miles or too short by hundreds of feet.

Additionally, by providing this vertical reference framework, the tide gages of Alaska will have a common reference frame for comparison, so that local changes to sea level can be compared against the global frame and greater understanding of the causes of these local signals can be studied.

Furthermore, monitoring of changes to the gravity field will occur in both the Alaskan and northern Canada regions as part of an international collaboration on GRAV-D. The changes to gravity seen in that region will be due to two factors – the post-glacial rebound of the Hudson Bay region, and the melting of glaciers in Alaska and Canada. GRAV-D will therefore be a strong contributor to many Arctic science plans.

Sustain Satellite-based Earth Observations

Summary: *The GRAV-D project both depends upon, and has the capacity to serve as a calibration for, satellite based gravity missions such as GRACE and GOCE and satellite based altimetry missions such as JASON.*

While GRAV-D is an airborne and terrestrial operation, it has strong ties to satellite missions. First of all, GRAV-D provides localized information on Earth's gravity field which satellite missions (such as GRACE, CHAMP or GOCE) miss. In this way, GRAV-D enhances the usefulness of these missions.

Secondly, GRAV-D will provide very detailed gravimetric information over the ocean regions, something which has previously been determined only through indirect sensing by satellite altimeters, such as JASON. Therefore GRAV-D provides a check on this indirect sensing methodology.

Finally, GRAV-D will incorporate occasional “long line” surveys, spanning an entire continent using special aircraft. Such a long, continuous, accurate gravity survey will be provided as a method of independently calibrating the gravity field models which come from satellite missions (again, GRACE, CHAMP or GOCE).

Conclusions

For the reasons outlined above, and in fulfillment of NOAA's mission as a whole to understand and predict Earth's environment, the GRAV-D project currently underway in NOAA will deliver not only significant socio-economic benefit but also strengthen and improve many diverse aspects of NOAA Science.