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*NOAA's National Height Modernization  
Program  
National Partner Meeting  
Final Report*

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*Silver Spring, Maryland*

*June 21, 2012*

## Contents

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Preface .....	3
NGS Reports .....	3
Welcome, Juliana Blackwell .....	3
HMOD Accomplishments and Future Plans, Renee Shields .....	3
Strategic and Ten-Year Plans, Dru Smith .....	4
OPUS Improvements, Neil Weston .....	4
National Adjustment of 2011, Renee Shields .....	5
HMOD Special Projects, Renee Shields .....	5
GRAV-D, Vicki Childers .....	5
Geoid Update, Dan Roman .....	6
State Reports.....	6
Illinois, Sheena Beaverson .....	6
Louisiana, Joshua Kent .....	6
Mississippi, David Mooneyhan & Denis Riordan .....	6
North Carolina, Scott Lokken .....	7
South Carolina, Dick Woods.....	7
Texas, Gregory Hauger.....	8
Alabama, Renee Shields.....	8
Indiana, Boudewijn van Gelder.....	8
Questions and Answers .....	8
Asked throughout NGS reports:.....	8
Asked throughout state reports: .....	9
Asked via webinar system:.....	10
Agenda .....	12
Attendees.....	13
Appendices.....	14

## Preface

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This meeting was scheduled after Height Modernization Partners expressed an interest in meeting annually at a Partner Meeting held in conjunction with a Lidar Workshop in August, 2011. The meeting provided an opportunity for NGS to find out about issues that impact state partners, primarily state agencies and universities. NGS discussed new and updated products and services directed at improving the accuracy and accessibility of elevation information, and its partner agencies shared lessons learned and best practices from ongoing and past projects. Accurate height information benefits numerous sectors including transportation, emergency response, agriculture, and natural resource management, and the National Height Modernization Program has funded partner organizations at varying levels in 18 states since 2001. As resources remain scarce, coordinating similar efforts and collaborating on related projects will become even more critical to efficiently provide accurate heights across the country.

## NGS Reports

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### Welcome, Juliana Blackwell

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Juliana Blackwell welcomed and thanked everyone for their attendance. Then Juliana discussed some of the challenges faced by the federal government and states in the past year, including travel restrictions that have severely limited the ability to attend meetings and conferences. Although these challenges were expected to continue, NGS is still listening and wants to find ways to work with our partners. There are still resources to manage a National Height Modernization Program, and NGS wants to identify partnering opportunities that respond to key priorities addressing national issues as well as local needs. Some of those opportunities include research projects, products that need updating, things that can support the national efforts. Juliana briefly explained that NGS is preparing the next Ten-Year Plan, which will be shared with stakeholders upon completion of the draft. Finally, Juliana mentioned the postponement and cancellation of upcoming events. The Real Time Network (RTN) Symposium scheduled for July has been postponed, and it is hoped to be re-scheduled in September. The Geospatial Summit, planned to coincide with the Esri Survey Summit in July, was canceled. However, NGS is working with Esri to add a geodesy track to the Esri Survey Summit. Finally, Juliana mentioned the intent to schedule a face-to-face meeting in the Gulf Coast area in late spring 2013.

### HMOD Accomplishments and Future Plans, Renee Shields

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Renee Shields briefly outlined some of the activities and accomplishments completed since the August 2011 Partner meeting that support height modernization objectives, including updated and new products, like improvements to NGS datasheets and the Leveling Online Computation User Service. Renee also mentioned projects including the Floodplain Mapping pilot project completed in North Carolina in collaboration with FEMA and the NC Floodplain Mapping Program, the geoid slope validation survey completed in Texas, and the special leveling adjustments that have been done in Wisconsin and the Gulf Coast to support GEOID12. To help support the National Adjustment project and the Gulf Coast Height Modernization project, Brian Shaw developed a GIS toolkit that was used for analysis of adjustment results throughout the process. These tools will eventually be packaged and available to the public. Renee then outlined the goals of the National Height Modernization Plan,

a strategic and operating plan that has been drafted to support the NGS strategic plan and Ten-year plan updates. The NHMP will be integrated with the revised NGS Ten-year plan over the coming months. (See Appendix for slides with more information.)

## Strategic and Ten-Year Plans, Dru Smith

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Dru Smith briefly introduced the reasons the NGS Ten-Year Plan is being revised. Since the current Ten-year Plan was written 5 years ago, it was time to revisit that plan to see where NGS is on track, not on track, or needs to change direction to respond to changing and emerging user needs. This evaluation of the current plan was done at the NGS leadership meeting in April 2012. Dru also mentioned a few things that the previous plan did not have in it or that have changed how NGS is looking at the plan:

- GRAV-D is well on its way, although the project completion goal is now 2022 rather than 2018 because funding support was less than anticipated.
- NGS has now had some training in the art of strategic planning and project management, how to create a plan with consistent language regarding Goals, Objectives, and Strategies.
- The previous plan was a list of big ideas without clearly explaining how to get there, and seemed to presume NGS had unlimited staff resources.
- NGS day to day mission operations include activities that consume as much as 90% of staff time and resources, so these efforts need to be reflected in the updated plan.

The new plan will be slimmer with large high-level goals, including replacing NAVD 88 and NAD 83. NGS will be assigning individuals to lead those high level goals, and then objectives as well as strategies with milestones will be developed in house. The plan will describe what NGS believes needs to happen, but Dru wants to hear from the partners if, from the stakeholder point of view, NGS is on the right track. If you are interested in receiving and reviewing the draft plan, email Dru and he will see you are on the email group list. Dru expects to have a plan out by mid-summer with a request that comments come back before the end of August. There will not be radical changes from the previous plan to this one, just more focus in this version. The target is to release a final new plan in January 2013.

## OPUS Improvements, Neil Weston

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Neil Weston explained that OPUS-S and OPUS-RS are both still supporting two reference frames until the release of GEOID12, and there will likely be some overlap after the release. Users should note that current solutions using the new reference frame will not generate an orthometric height. Neil also explained a tool being developed to replace OPUS-S, which is internally called OPUS-NET. The replacement tool will use 10 IGS stations and baselines from 3 Continuously Operating Reference Stations (CORS), doing a true least-squares solution, so that discrepancies among the 3 CORS will not contaminate the solution. Regarding OPUS-Projects, Neil reported that Mark Schenewerk continued to make improvements, and that the tool is being tested internally and externally. Training to use OPUS-Projects is suspended until it becomes more clear when the tool will be operational, which depends on further analysis comparing OPUS-Projects solutions to the traditional “bluebook” method using ADJUST.

## National Adjustment of 2011, Renee Shields

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Mark Eckl, Operations and Analysis Division Chief, and Project Manager for the new vertical datum, was unavailable to attend the meeting, so Renee summarized the National Adjustment of 2011. The adjustment is complete, and has been loaded into NGS' test database, where Dan Roman will extract the data for GEOID12. The project included 80,872 GNSS-observed stations, of which 1,195 are constrained CORS. The adjustment of the CONUS (Conterminous U.S.) was done in two parts, the first, or primary network was composed of the more recent or more accurate surveys, and the secondary network adjusted the remaining stations to the Primary. Alaska, while connected to CONUS through the connections to the CORS network, only has a few single long lines to CONUS, and so was adjusted separately. Hawaii and the Pacific territories were adjusted to the Pacific and Marianas plates as appropriate. The results will be released coincident with GEOID12. There is a lot of interest in doing an adjustment of Height Modernization GPS projects to compute a set of consistent GPS-derived NAVD 88 heights, but no final decision will be made until NGS assesses its priorities and what resources will be needed.

## HMOD Special Projects, Renee Shields

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Renee described the Height Modernization Special Projects Steering Committee, a work group developed at the request of Mark Eckl to manage completion of several on-going and planned leveling adjustments in areas of concern. In Wisconsin, a comprehensive readjustment of all the leveling completed as part of their height mod efforts was needed to correct some problems that had crept into the vertical network as a result of the way phases of the project had been pieced together. The problems had caused inconsistencies at the borders with other states, and at several Great Lakes water level stations.

In the Gulf Coast region, the MSDOT completed a leveling project in 2009 that extended across Mississippi, Alabama, and into Florida. This data was used to update the Vertical Time-Dependent Positioning model (VTDP), and the 2009 observations and other historic observations from the VTDP study were adjusted to provide 2009 epoch NAVD 88 heights. These in turn were used as control for secondary adjustments, feathering the network to ensure consistent bench marks to the north of the new leveling would be available as input to GEOID12. Some secondary leveling to fit the new control was also done in Alabama and a small area of Florida, also completed in time for GEOID12.

A statewide GPS Height Modernization project done in 2009 by the MSDOT to go with the leveling, and an NGS project done in Louisiana in 2010, both were included in National Adjustment of 2011, producing accurate ellipsoid heights. These contributed bench marks to the geoid model. Those marks needing NAVD 88 heights from the GPS will be adjusted after GEOID12 is complete. Other leveling adjustments are planned for the region after GEOID12 is complete. A secondary benefit of performing the secondary adjustments of past leveling observations is the opportunity to train additional personnel at NGS in the art of doing leveling adjustments, and in so doing, identify where improvements are needed in guidelines, software, or procedures. Renee anticipates this Special Projects Steering Committee will continue when these projects are complete, evaluating locations around the country where more rigorous analysis of the vertical network is needed, such as the Harris-Galveston Coastal Subsidence district, or other states where localized movement or data gaps exist.

## GRAV-D, Vicki Childers

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Vicki Childers gave an overview of the status of GRAV-D, including background of the program and goals, and what surveys have been completed and are being done now and planned for the near future. Vicki

mentioned partnering opportunities, both within the industry and other federal agencies, some that have been successful, and some not so much. Vicki also described the Texas geoid slope validation survey in a little more detail, and how the data collected showed that the GRAV-D project would provide the data that was the piece of the puzzle needed to achieve the 1-centimeter geoid. (See Appendix for slides with more information.)

## Geoid Update, Dan Roman

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Dan Roman provided an update on the progress of GEOID12, with the most important information being that he expects it will indeed be completed by June 29th. The USGG2012 gravitational model has been complete for some time and was just waiting on the GPS on bench marks provided by the combined National Adjustment of 2011, and all the special project leveling adjustments. Renee provided heights from the latter the previous week, and those are being compiled and reviewed, and input provided by advisors and other partners, and the model itself would be constructed over the weekend. The week of June 25th would be dedicated to one last review of the results, and testing datasheets and all the utilities that absorb the geoid model to make sure everything is up to date. (See Appendix for slides with more information.)

## State Reports

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### Illinois, Sheena Beaverson

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Sheena presented information about the goals, funding, and ongoing projects of the Illinois Height Modernization Program (ILHMP). The program has been successful in securing State Planning and Research (SPR) funding from US DOT Federal Highway Administration with in-kind match from state DOT; as a result, there has been a big ramp-up this past year. Then, Sheena discussed the two primary thrusts of the program: leveling and lidar. Being part of a University makes it easier to have the leveling efforts cross state lines, and there is growing internal support for the program. The most effective means to attract supporters is creating one-pagers that show how others are using and applying the improved elevation information (especially lidar data where the improvement in imagery is dramatic). [See Appendix for slides with more information.]

### Louisiana, Joshua Kent

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Josh introduced that the state CORS network is a critical part of the LA Height Modernization Program. Of 65 CORS, 26 are National CORS. LA is currently submitting two more CORS to become part of the national network, and these are in the New Orleans area specifically to look at deep and shallow subsidence. There is increasing application of the RTN network; for example, RTNs can now be used for certification of levee heights with local boards and commissions. Louisiana Spatial Reference Center (LSRC) is also working with FEMA locally to use RTN for floodplain mapping. Josh added that they are waiting for the release of the results of the National Adjustment of 2011 and GEOID12 because, until that time, LA is operating in two systems. A remaining challenge is that LA just desperately needs orthometric heights.

### Mississippi, David Mooneyhan & Denis Riordan

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David Mooneyhan explained the Mississippi Height Modernization Program, run out of the University of Southern Mississippi, operates a CORS network, currently with 52 stations. They are currently upgrading the network, then will do a network adjustment. There are also plans to upgrade the back-up site, too, based on lessons learned. There are plans to add 10 more quality CORS, working closely with local DOT folks to carefully select the best location. There are two primary partners of the program right now. There is a fee for service agreement with the DOT that gives access to CORS data and the real time network. There is also a partnership with the National Park Service to install CORS on each barrier island co-located with meteorological equipment to help a scientific effort updating the shoreline delineation. Education efforts include partnering with all state and community colleges to share data with the surveying and GIS programs. There is also a CORS at the entrance to a brand new science center where school children will visit. Finally, MS would like to host the National Height Modernization Partner meeting next year probably near the Gulfport or Biloxi area.

Denis Riordan briefly discussed the recent statewide HMOD project that was initiated by MS DOT. Some of the planning originated with Kurt Shinkle, former NGS state advisor, and it used both GPS and leveling. Completion of the project was a true partnership effort, but its publication did get caught up in the National Adjustment of 2011 and GEOID12 projects. However, the adjustments of these new surveys were completed in time to contribute to the National Adjustment and GEOID12. The results will greatly improve the geoid model, especially since the project crossed state borders. Data and reports will be made available soon, and a GPS vertical adjustment will be completed after the National Adjustment and geoid model are done. Denis also mentioned efforts tying control to USGS stream gages, and he plans to contact the local District office to ensure any data collected makes it into the USGS database.

### North Carolina, Scott Lokken

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Scott mentioned that in NC, others are completing HMOD on their own including the rail ways completing their right of way work. The NC CORS network is composed of 81 stations, with 3 new coming online soon. Another new CORS is replacing one destroyed by Hurricane Irene, at a critical location for the RTN. NC's RTN, shares stations across SC, and they negotiating a similar arrangement with TN. NC uses a twitter site to update users on status of RTN and upcoming classes. Scott explained how NC is using a google maps interface to provide easier access to the NC and other databases, search by street address, check visibility diagrams, and look at flood plain information. Scott added that EDM baselines are still being used and a workshop was held last summer. NC continues outreach efforts through classes and workshops, but has also started creating instructional videos for common questions that come up. [See Appendix for slides with more information.]

### South Carolina, Dick Woods

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Dick explained the greatest benefit of the program has been establishing accurate elevations in parts of state not accessible via terrestrial leveling, for example offshore islands where connections to tidal datums were also made. Additionally, there has been a tremendous cost-savings using GPS instead of relying solely on terrestrial surveying. Beginning in 2001, the goal was to complete county wide HMOD surveys across the state, and 85% of the counties have been surveyed at this time. Cooperative efforts have existed, especially with North Carolina, speeding up projects and adding control along the border. Dick also highlighted how challenge that having the field staff reduced in half caused a successful change in the normal process of completing geodetic work. Now, the state works very closely with local surveying chapters and local government officials to get additional field support, building a close relationship and educating those who assist.

## Texas, Gregory Hauger

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Greg talked about a major project in Jefferson County that came in the aftermath of Hurricane Ike. The analysis of the project with 22 new marks and a new CORS was recently completed and did show vertical change occurring. The next project ramping up is in partnership with USACE, and it involves tying in existing and historic tidal bench marks all along the coast. By the end of the project, about 120 marks will be observed, then the data processed and analyzed.

## Alabama, Renee Shields

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John Russell was not able to attend but emailed some comments to Renee. ALDOT is looking forward to the using the 2010 Multi-year CORS Solution positions, the results of the National Adjustment of 2011, and GEOID12 as a consistent system, particularly incorporating the new data provided recently from ALDOT including:

- The GPS campaign in 2004/2005 to tie our existing First Order Network to the CORS
- The many miles of leveling to those marks and others in hopes of improving the GEOID model.
- The statewide CORS network that has resulted in reliable and faster positioning through OPUS and with RTK survey methods.

John also highlighted one of the many benefits of HMOD in Alabama is the relationships developed with local government surveyors/engineers, private surveyors, the Precision Agriculture group, NGS, and other Height Modernization states.

## Indiana, Boudewijn van Gelder

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Indiana has had a RTN since February 2010, supported by 45 stations. They also began a pilot project last year to gauge the cost of densifying the network. The effort moved forward in the Hamilton County Surveyors Office with support of Joe Mullens, and the local office completed recon for an estimated \$10,000. Volunteers from state offices and private companies then helped complete GPS observations in a field campaign (35 marks were observed with at least three 45 minute sessions each). Volunteers could receive continuing education credits, and the effort was estimated to be equivalent to \$35,000. The next step to complete the project requires identifying funds and/or volunteers for data processing and analysis.

## Questions and Answers

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### Asked throughout NGS reports:

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**Q (Hauger):** Is OPUS Projects ever going to be used to get observations into the NGS-IDB? The processing is much easier, but I have heard it will not replace bluebooking.

**A (Blackwell):** One of objectives of the revised ten-year plan is to "re-invent" bluebooking. There is not a good mechanism to get information from OPUS-Projects into the NGS IDB. We are looking at ways to re-invent QA/QC data and accept it, but we do not have a timeline when that functionality will be available.

**Q:** Is there a date when GEOID12 will be available?

**A:** June 29, 2012.

**Q:** Where will the next Geoid Slope Validation Survey (GSVS) be?

**A:** Somewhere farther north and at a higher elevation than TX, perhaps Nebraska or Kansas. The 3<sup>rd</sup> GSVS will likely be in an area of rougher terrain.

**Q (Gilbert):** Why are the Great Lakes a GRAV-D priority, and is the entire US-Canada border a priority?

**A (Vicki):** All the border will eventually be flown, but in general the Canadian border is not a priority. The Lakes are important because of the plan for a new IGLD. All that said, opportunities can sometimes dictate changes in priorities.

**Q (Marti):** Why are some lower priority areas along the border with Canada (i.e. not along the Great Lakes) being flown?

**A (Vicki):** When bad weather interferes with the schedule we adapt the schedule to fly other convenient locations near our base airport.

**Q (Renee):** What are the plans for flying along the Mexican boundary?

**A (Vicki):** We have tried to contact them to discuss our flights over their air-space, but no one there has responded.

**Q (Renee):** Have you found opportunities or considered offers with States to use their aircraft.

**A (Vicki):** We have tried it but it was difficult to make it work. We had an offer in SC and it would have been a great rate, but we couldn't figure out how to transfer money to them.

**Q (Mulcare):** Does NGS still have the Applanix POS LV (an integrated, turnkey position and orientation system).

**A (Scott Lokken):** The unit still exists but the truck with the mount was surplus.

**Q (Renee):** What is Mexico's plan for updating their network? They had been talking about re-leveling their entire network.

**A (Dan):** They are beginning to think more about a gravimetric geoid.

## [Asked throughout state reports:](#)

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### *ILLINOIS*

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**Q (Renee):** Are you finding many marks in the database don't exist anymore?

**A (Sheena):** Mike Blumhoff would be able to answer better, but we are working with the DOT and local surveyors who know what is out there. Whatever can be found, we are passing through even if it requires going a lot out of the way.

**Q (Marti):** How many counties are in IL, and who do you contact at the county to inquire about acquiring data?

**A (Sheena):** There are 102 counties, and they are all different in who to contact and how much they willing they are to share data. Downloading the data is clunky right now, but there is no interactive service for viewing data.

**Q (Neil):** Do you have plans to update lidar data after this first coverage is complete?

**A (Sheena):** Our Federal Highway Administration (FHWA) State Planning and Research (SPR) funding is only for a one time, five year window and more strongly focused on leveling. Our first lidar acquisition in the state for a

complete county was in 2004, which set the clock ticking. Thus, it is doubtful that we will achieve statewide lidar coverage for the first time, let alone a plan for re-flights.

## *LOUISIANA*

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**Q (Josh):** Will NGS be publishing new vertical observations from the 2010 Louisiana GPS survey?

**A (Renee):** NGS will complete a vertical adjustment of the 2010 GPS survey, but you may actually lose a few marks because the 2010 GPS survey did not reach all marks from the 2006 survey. Hopefully, with the new and improved GEOID12, then a denser network can be built out with OPUS-DB.

## *MISSISSIPPI*

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**Q (Renee):** Have you been in touch with local USGS to get updated heights at stream gages into database?

**A (Denis):** Yes I have been in touch with local contacts, but have not specifically discussed publishing the updated elevations in the USGS database.

## *TEXAS*

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**Q (Renee):** Has there been any work done on the digital leveling tool?

**A (Greg):** Rick Smith has been busy with other responsibilities. He is planning to work on it again and address some "fixes" that did not work. At this time, nothing has changed in several months and no new coordination has developed with Trimble.

## *INDIANA*

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**Q (Dr. Van Gelder):** How should we go about updating information in the Indiana HMOD page at the NGS site?

**A (Renee):** NGS welcomes any state to submit new material for the web pages, including articles, reports, news stories, accomplishments, or links to material on their own sites.

## *Asked via webinar system:*

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**Q (Donald Mulcare):** Will NGS be willing to loan gravity meters to partners willing to perform work to NGS standards? Do standards and specifications now exist?

**A:** Loaning of equipment, when it has occurred in the past, has been agreed to on a case-by-case basis. A more formal policy, while helpful, does not currently exist. NGS has been working on standards and specifications for terrestrial relative surveys, but they are not complete.

**Q (Donald Mulcare):** While the LOCUS tool release is good news as it represents something being done with respect to leveling, it does not have the utility of Linetool. Of course, Linetool no longer works and I suspect is an orphan. How Linetool differs is that it includes the ability to find level lines and retrieve the data files. Will the functionality of Linetool be added to LOCUS or will Linetool be fixed?

**A:** NGS knows Linetool is broken and is working to develop tools that improve user access to vertical data

**Q (Donald Mulcare):** The current bluebooking for GPS projects doesn't make any sense to me. The occupation records due to the limitations in field size cannot be used for such simple queries as what instrument or antenna

was used when and where. Users of the NGS vector reduction software, PAGE-NT, already have, in the many files it creates the overwhelming majority of information that should constitute the metadata for a project. IF the RINEX header in the observation file is complete and correct most of what is needed for a "modern bluebook" is already done. Meaningless data like cable lengths, surface meteorological data and observer initials should be purged.

**A:** A modernized version of storing and recalling GPS (or GNSS) project metadata would be welcomed by most, if not all, people working with that type of survey data. Purging the various data types might be appropriate, but the changes are not trivial given the way NGS handles software revisions. In the meantime, the extra data types need not be seen as harmful.

**Q (Donald Mulcare):** Why doesn't NGS follow the NC Geodetic Survey and add visibility diagrams to your datasheets? Digital photo uploads are already allowed. Having a visibility diagram could be a real benefit to users who now must rely on the "Usable" or "Not useable" options in current description. When is a GPS unusable? Some folks consider any obstructions to make it unusable; some think any site you can set an antenna over is usable. A visibility diagram would help.

**A (Renee):** There is now an active datasheet committee, and this idea has been submitted to them for consideration. We are currently working on numerous updates to the datasheet, but in the future hope to improve the way we deliver control data to the public.

**Q (Donald Mulcare):** Any chance the TX Geoid Slope Validation Project data will be made available to the public?

**A (Dru):** GSVS11 data is generally organized, and a data report has been written. It has been held back from public release until the official paper proving the successful 1 cm geoid modeling is written and published. The paper could be sent out in late August or early fall, and then the data will be released.

**Q (Donald Mulcare):** In a recent lab for my class, we analyzed the NGS data available for AH1762. This included datasheet data and OPUS-DB data. It appears obvious to me that the published height, shown as based on GPS OBS, is wrong at the decimeter level. I do not know who at NGS I report this finding for their attention. This brings to mind the issue of NGS designating a contact for such issues. Comments?

**A:** When discrepancies are identified, you should contact [ngs.infocenter@noaa.gov](mailto:ngs.infocenter@noaa.gov). Ultimately, your message would be forwarded to the OPUS team or Geoid team depending on where we believe the inconsistency may be coming from.

## Agenda

- 1:05 - 1:15      **Welcome, Introductions**  
Ms. Juliana Blackwell, Director, NGS
- 1:15 - 1:35      **National Height Modernization's Recent Accomplishments and Approach Forward**  
Ms. Renee Shields, Height Modernization Manager, NGS
- 1:30 - 2:40      **Presentations from states: Accomplishments, lessons learned, challenges**  
IL – Ms. Beaverson , LA – Dr. Kent, MS – Mr. Mooneyhan, NC – Mr. Lokken
- 2:40 - 2:50      **Strategic Plan & Ten Year Update**  
Dr. Dru Smith, Chief Geodesist, NGS
- 2:50 - 3:10      **Presentations from states (continued)**  
SC – Mr. Woods, TX – Mr. Hauger, AL – Ms. Shields, IN – Dr. van Gelder
- 3:10 - 3:25      **Break**
- 3:25 – 3:35      **OPUS Improvements**  
Dr. Neil Weston, Spatial Reference System Division Chief, NGS
- 3:35 – 3:45      **National Adjustment of 2011 and HMOD Special Projects**  
Ms. Renee Shields, Height Modernization Manager, NGS
- 3:45 – 4:45      **GRAV-D & Geoid Update**  
Dr. Vicki Childers, GRAV-D Project Manager, NGS  
Dr. Dan Roman, Research Geodesist, NGS
- 4:45 – 5:00      **Closing, Wrap-up, summarize actions, plan next meeting**  
Ms. Renee Shields, Height Modernization Manager

## Attendees

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Name		Affiliation
<b>Mark</b>	Guerrero	Colorado Department of Transportation
<b>Kevin</b>	Hoffman	Colorado Department of Transportation (Woolpert Inc.)
<b>Sheena</b>	Beaverson	Illinois State Geologic Survey
<b>Joshua</b>	Kent	Louisiana State University
<b>Randy</b>	Osborne	Louisiana State University
<b>Shawn</b>	Roy	Michigan Department of Transportation
<b>Bryce</b>	Larsen	Montana Department of Transportation
<b>Earl</b>	Burkholder	New Mexico
<b>Gary</b>	Thompson	North Carolina Geodetic Survey
<b>Christine</b>	Gallagher	NGS
<b>Daniel</b>	Winester	NGS
<b>Juliana</b>	Blackwell	NGS
<b>Renee</b>	Shields	NGS
<b>Dave</b>	Doyle	NGS
<b>Neil</b>	Weston	NGS
<b>Tim</b>	Hanson	NGS
<b>Dru</b>	Smith	NGS
<b>Vicki</b>	Childers	NGS
<b>Gilbert</b>	Mitchell	NGS
<b>Marti</b>	Ikehara	NGS (CA advisor)
<b>Pamela</b>	Fromhertz	NGS (CO advisor)
<b>David</b>	Newcomer	NGS (FL advisor)
<b>John</b>	Ellingson	NGS (WI advisor)
<b>Dave</b>	Rigney	NGS (MI advisor)
<b>Denis</b>	Riordan	NGS (MS advisor)
<b>Scott</b>	Lokken	NGS (NC advisor)
<b>James</b>	Richardson	NGS (NE advisor)
<b>William</b>	Stone	NGS (Southwest Region Advisor)
<b>Boudewijn</b>	van Gelder	Purdue University
<b>John</b>	Canas	Scripps Institute of Oceanography,
<b>Dick</b>	Woods	South Carolina Geodetic Survey
<b>Matt</b>	Wellslager	South Carolina Geodetic Survey
<b>David</b>	Steele	State of Washington DNR
<b>Donald</b>	Mulcare	Texas A&M Corpus Christi
<b>Greg</b>	Hauger	Texas A&M Corpus Christi
<b>David</b>	Mooneyhan	University of Southern Mississippi
<b>D David</b>	Moyer	Wisconsin Department of Transportation (DD Moyer & Associates)

## Appendices

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Powerpoint presentations:

1. National Height Modernization's Recent Accomplishments and Approach Forward  
Ms. Renee Shields, Height Modernization Manager, NGS
2. Illinois Accomplishments, lessons learned, challenges  
Ms. Sheena Beaverson , Illinois Height Modernization Program Manager, ISGS
3. North Carolina Accomplishments, lessons learned, challenges  
Mr. Lokken, North Carolina State Geodetic Advisor, NGS
4. GRAV-D & Geoid Update  
Dr. Vicki Childers, GRAV-D Project Manager, NGS
5. GRAV-D & Geoid Update  
Dr. Dan Roman, Research Geodesist, NGS



## National Height Modernization: Recent Accomplishments, Approach Forward

Renee Shields  
June 21, 2012.

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### Height Modernization Accomplishments

- Working group activities
  - USGS Stream gage datum updates
  - FGCS Vert Ref System Work Group
  - Height Mod Special Projects Steering Committee
- Projects
  - Updating HTDP (e.h.) – UAF Contract
  - Texas Geoid Slope Validation Survey: 2012, 2013
  - Support for ECO: Ecosystems and Climate Operations
  - Release of Floodplain Mapping Pilot Prj Report

### Height Modernization Accomplishments

- Tools, Models
  - LOCUS, Vdatum
  - ArcGIS Tool box in development – used for NA2011, Special projects
- Datasheet updates
  - Adding geoid model information
  - Revising publication in suspect areas

3

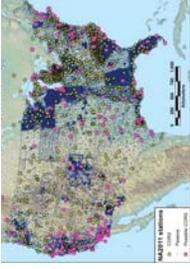
### Height Modernization Accomplishments

- Education, capacity building, outreach
  - Expand expertise in leveling adjustments – develop guidelines, training
  - Updates to website, podcasts
  - Workshops
  - Monthly meetings – NEEA update, reports on special projects
- Draft Strategic Plan for Height Mod

4

## Height Modernization Strategic Plan

- Improve access to NAVD 88 today
  - Identify areas of immediate critical need
  - Build infrastructure that will help access today, **and** support access in the future
- Prepare for transition to new vertical datum
  - Models, tools, guidelines, specifications
  - Education, outreach, capacity building



5

## Goal 1: NGS Understands User Capability to Get 2 cm Heights

- NAVD 88 today
  - Review data holdings: density of CORS, passive control, ties to tide gages, gravity data
  - Consider conditions: topography, dynamic processes, population, tree cover and extreme weather
  - Evaluate guidelines, models, tools
- Gravimetric geoid-based datum tomorrow
  - Define infrastructure needed to achieve 2 cm heights reference to new datum
  - Identify guidelines, models, tools that will need to be updated

6

## Goal 2: Strategically Address Gaps

### Goal 3: Maintain Access to Vertical Datum

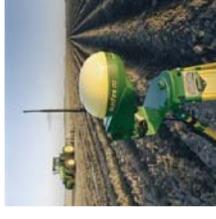
- NAVD 88 today
  - Recommend actions to address gaps/weaknesses in infrastructure – surveys, pilot projects, velocity models
  - Special attention to dynamic regions
  - Modify delivery of control: modify accuracies or expire outdated control
  - Support local communities' capacity to validate/maintain vertical control: guidelines, tools
- Gravimetric geoid-based datum tomorrow
  - Actions done today will support transition to new datum

7

## Goal 4: Education, Capacity Building



- Publications: technical journals, web site
- Training: workshops, webinars, conferences
- Capacity building: hands-on surveying and processing workshops
- Opportunities for collaboration: pilot and research survey projects



- Research grants: to test and develop guidelines, models, and tools
- Outreach: traditional and non-traditional user community

8

## Height Modernization will succeed if:

- NGS works with user community, federal and local agencies, universities
- Activities are multi-faceted, e.g. surveys
  - ... address gaps
  - ... test guidelines
  - ... provide opportunities to maintain core capabilities in NGS **and** train user community
- Activities are prioritized
  - Areas of critical need
  - Support access to NAVD 88 now **plus** transition to new datum

9



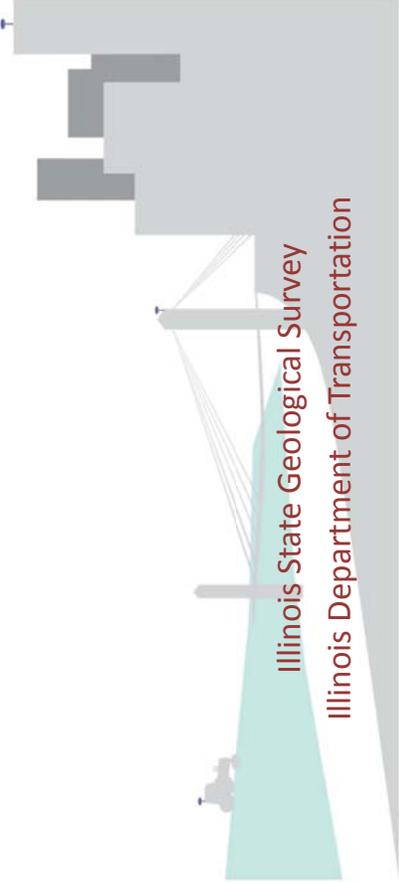
## Questions

Renee Shields  
Height Modernization Manager  
301-713-3231, x116  
Renee.Shields@noaa.gov

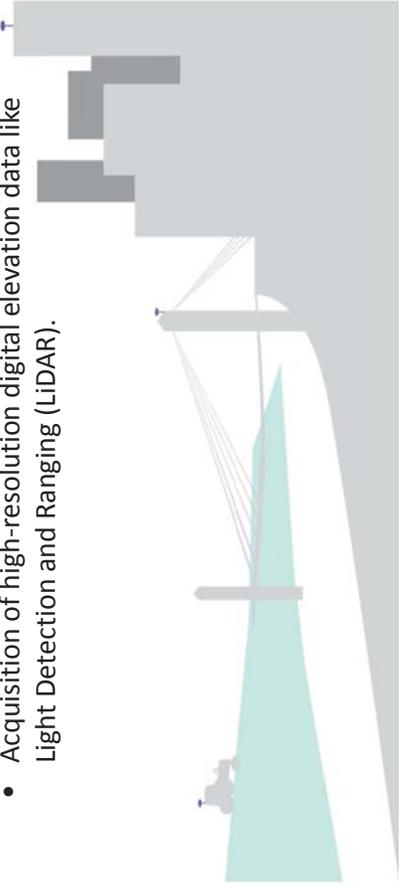
10

## Illinois Height Modernization Program

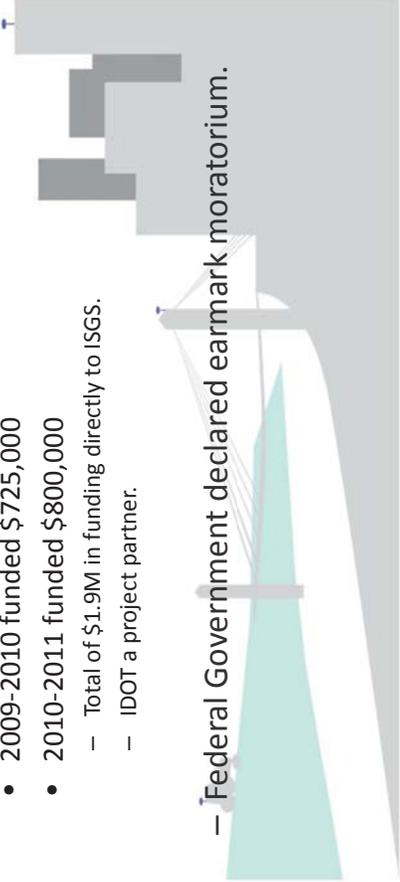
Illinois State Geological Survey  
Illinois Department of Transportation



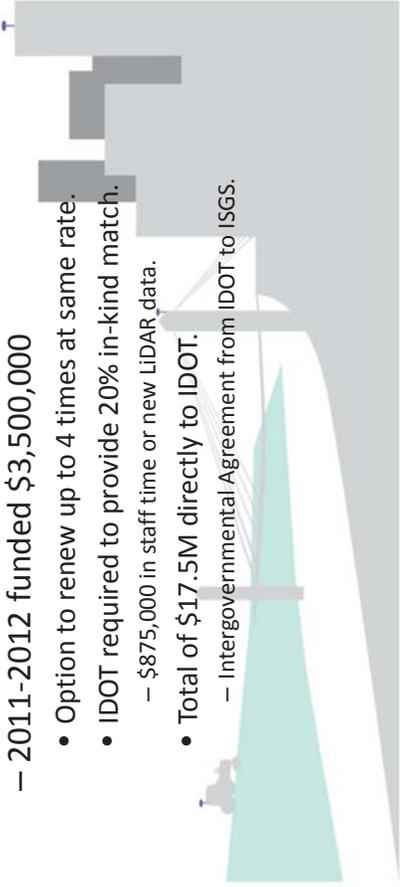
## Illinois Height Modernization

- Program Goals.
    - Installation of surveying benchmarks and geodetic leveling.
    - Acquisition of high-resolution digital elevation data like Light Detection and Ranging (LiDAR).
- 

## Illinois Height Modernization

- Years 1-3: funded by federal appropriations.
    - 2008-2009 funded \$300,000
    - 2009-2010 funded \$725,000
    - 2010-2011 funded \$800,000
      - Total of \$1.9M in funding directly to ISGS.
      - IDOT a project partner.
  - Federal Government declared earmark moratorium.
- 

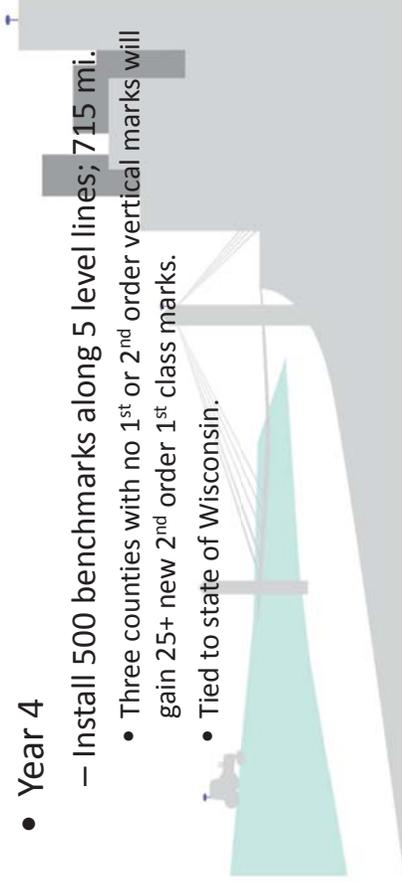
## Illinois Height Modernization

- Year 4: Federal Highway Administration, State Planning and Research (SPR) Program.
    - 2011-2012 funded \$3,500,000
      - Option to renew up to 4 times at same rate.
      - IDOT required to provide 20% in-kind match.
        - \$875,000 in staff time or new LiDAR data.
    - Total of \$17.5M directly to IDOT.
      - Intergovernmental Agreement from IDOT to ISGS.
- 



## Geodetic Leveling

- Years 1-3
  - Install 187 new benchmarks, visit 115 monuments.
- Year 4
  - Install 500 benchmarks along 5 level lines; 715 mi.
    - Three counties with no 1<sup>st</sup> or 2<sup>nd</sup> order vertical marks will gain 25+ new 2<sup>nd</sup> order 1<sup>st</sup> class marks.
    - Tied to state of Wisconsin.

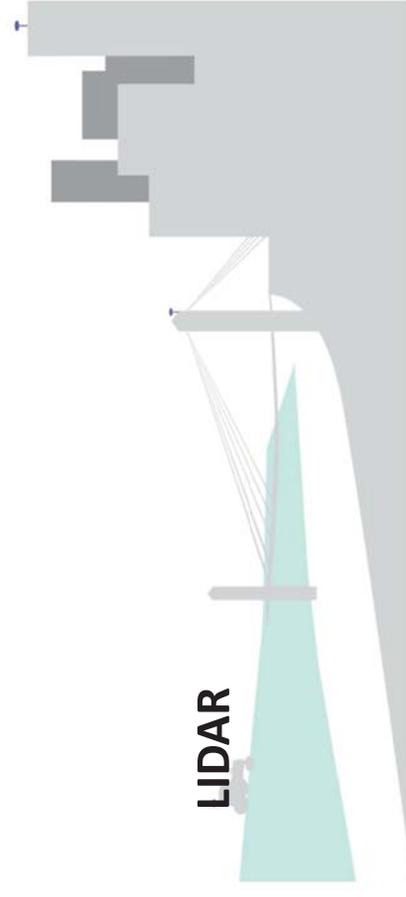
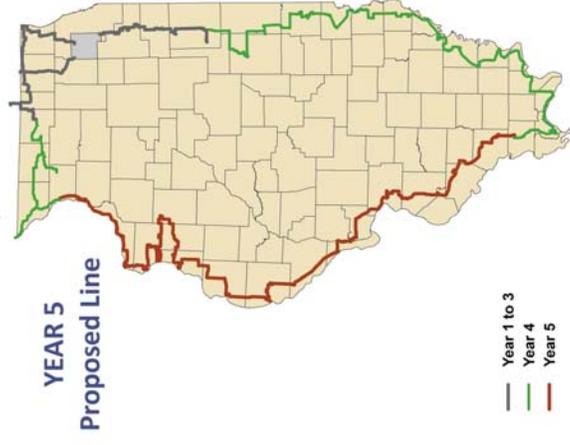


## Geodetic Leveling

- Setting a Baseline for Statewide Vertical Control
  - Years 1-4: about 1,000 miles and 1,000 marks.
  - First time Illinois has been leveled north-south.
  - Year 5: install 623 new and 177 existing monuments.
    - Only 45 have elevation information.
    - Tie to Mississippi River lock and dams.
    - Tie to state of Iowa.

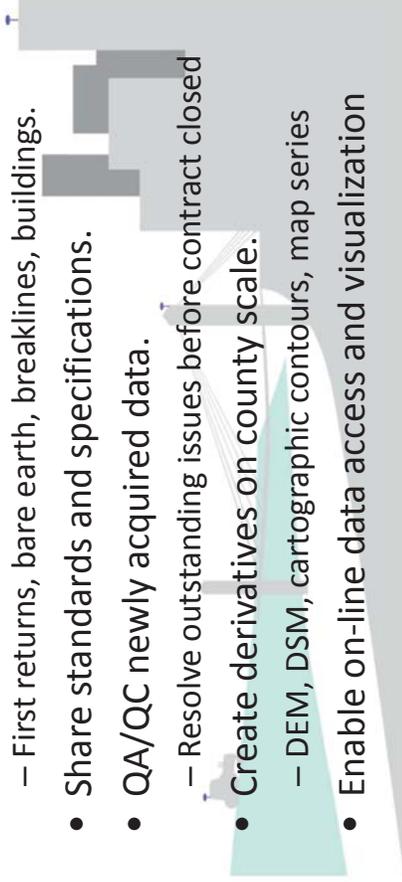


### Level Line Progress for Illinois



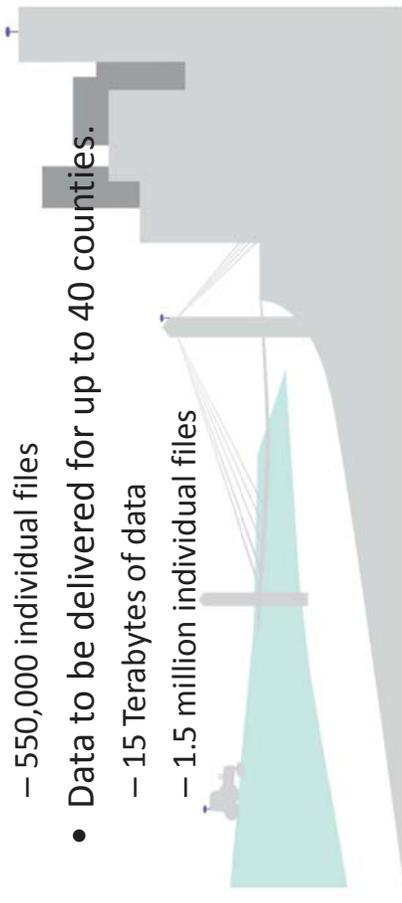
## ILHMP LiDAR: Project Goals

- Acquire, or establish data sharing agreements for, LiDAR and derivative elevation data.
  - First returns, bare earth, breaklines, buildings.
- Share standards and specifications.
- QA/QC newly acquired data.
  - Resolve outstanding issues before contract closed
- Create derivatives on county scale.
  - DEM, DSM, cartographic contours, map series
- Enable on-line data access and visualization



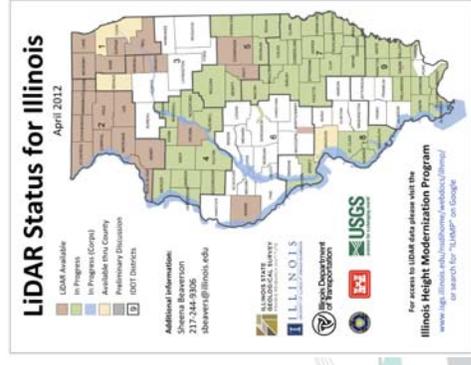
## ILHMP LiDAR Data

- Data for 22+ counties
  - 5 Terabytes of data
  - 550,000 individual files
- Data to be delivered for up to 40 counties.
  - 15 Terabytes of data
  - 1.5 million individual files



## ILHMP LiDAR Data

- LiDAR exist for brown, yellow counties.
- LiDAR contracted for green counties and river corridors.



USGS Elevation Data compared to Lidar Enhanced Elevation Data



Lidar Bare Earth DEM  
Pecatonica River, Winnebago County IL



USGS 30 meter DEM  
Pecatonica River, Winnebago County IL



Waterloo Quadrangle  
2012 LIDAR Bare Earth



# Illinois Height Modernization Program

## LiDAR Data Applications

Xiaodong Zhao and Donald E. Luman

### Morphology of Dune Complexes



1) 2009 LIDAR elevation image of central Whiteside County.

#### Whiteside County, Illinois

Sand dunes are a particularly prominent landform feature within the Green River Lowland of Whiteside County. Formed by wind action, most dunes have a windward slope that is steeper than the leeward slope, and are stabilized by vegetation cover under the current climate regime. Dune orientations and internal cross-bedding structure consistently indicate a prevailing wind direction in this region. Optically stimulated luminescence ages (OSL, or optical ages) of dunes in the Green River Lowland of Whiteside County range from 17,000 to 18,000 years ago. Dune sand is highly valued by industry, and is used for a variety of purposes, including in the production of glass, ceramics, and other materials.

Figure 1 is a color relief image produced from 2009 LIDAR elevation data showing a portion of the Green River Lowland. Dune height in the region ranges from a few feet to nearly forty feet. Figures 2-3 are



2) Close-up of two prominent parabolic dunes.



3) Perspective view of the two dunes.

close-up images of two larger parabolic dunes, both of which have a horizontal extent of 1/4 mile. The maximum height of thirty-five feet above the surrounding ground surface. The exceptional horizontal extent of these dunes is a result of the high quality of LIDAR elevation data makes it ideal for capturing the morphology of these dunes, which have heretofore not been mapped in this detail.

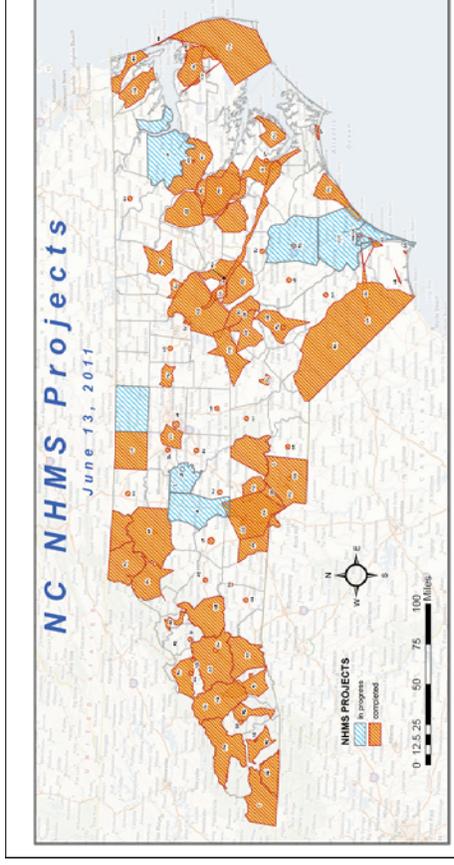
#### For Additional Information:

[www.lidar.usda.edu/shape\\_data/whiteside/whiteside\\_elev.html](http://www.lidar.usda.edu/shape_data/whiteside/whiteside_elev.html)



## North Carolina Geodetic Survey

June 2012 Update



## What is a CORS?

### • Continuously Operating Reference Station (CORS)

- A permanent Global Navigation Satellite System (GNSS) receiver, antenna (with a surveyed reference position), and support equipment
- NC CORS Network
  - Composed of 81 CORS
    - 3 new CORS have been installed
      - Salisbury (NCSA)
      - Roanoke Rapids (NCRR)
      - New Bern (NCNB)
    - 1 new CORS are being installed
      - Pea Island (NCPE)
  - Collects data 24/7 at 1 second intervals

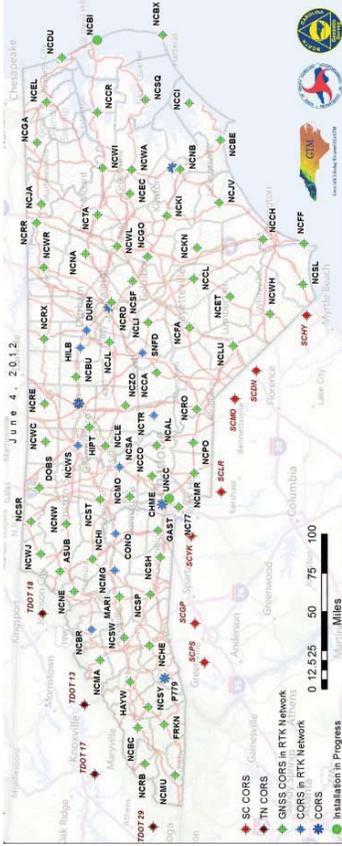


## Former Pea Island CORS

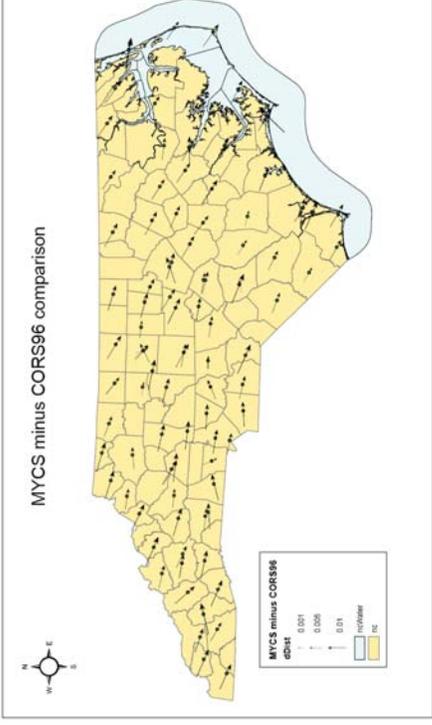




# North Carolina CORS plus bordering SC and TN CORS



# NAD83(2011) minus NAD83(NSRS2007)

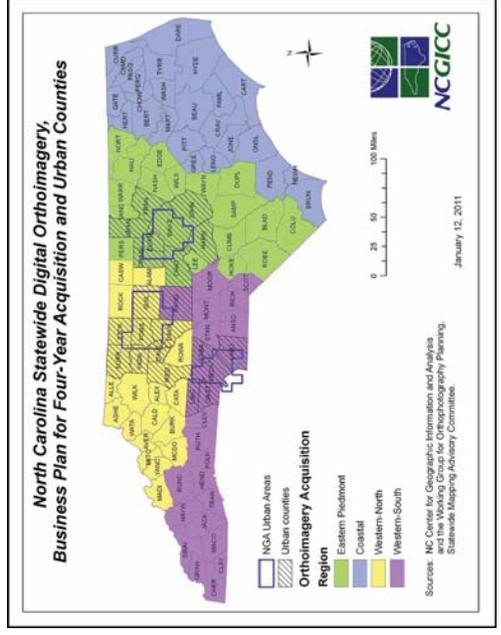


# NC Geodetic Survey on Twitter

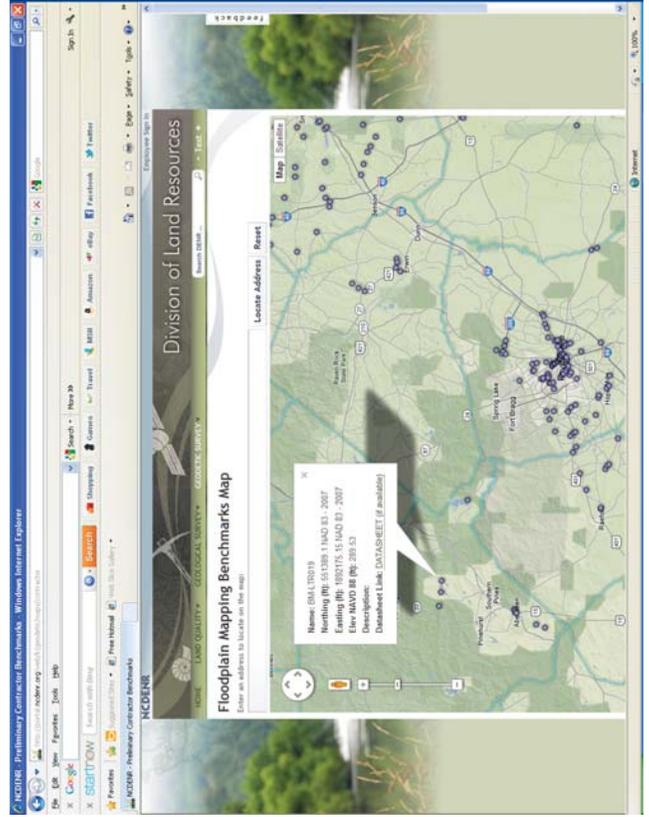
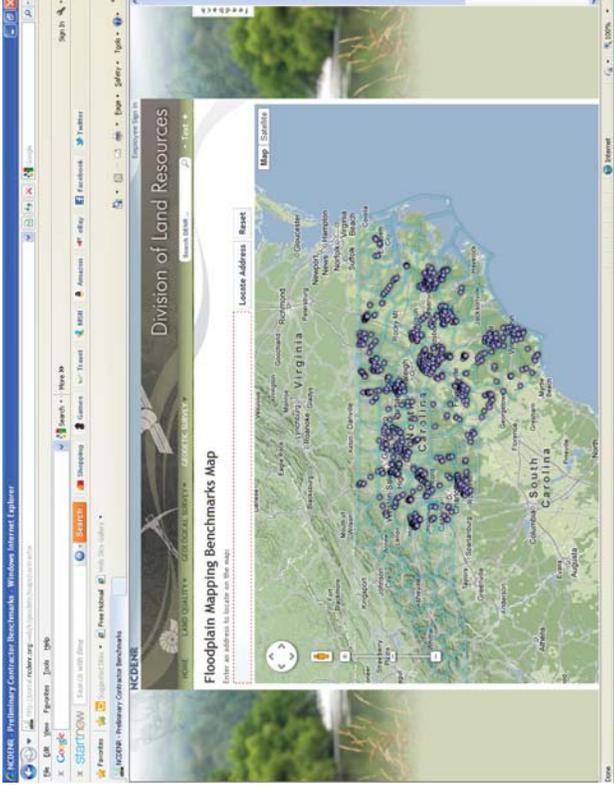
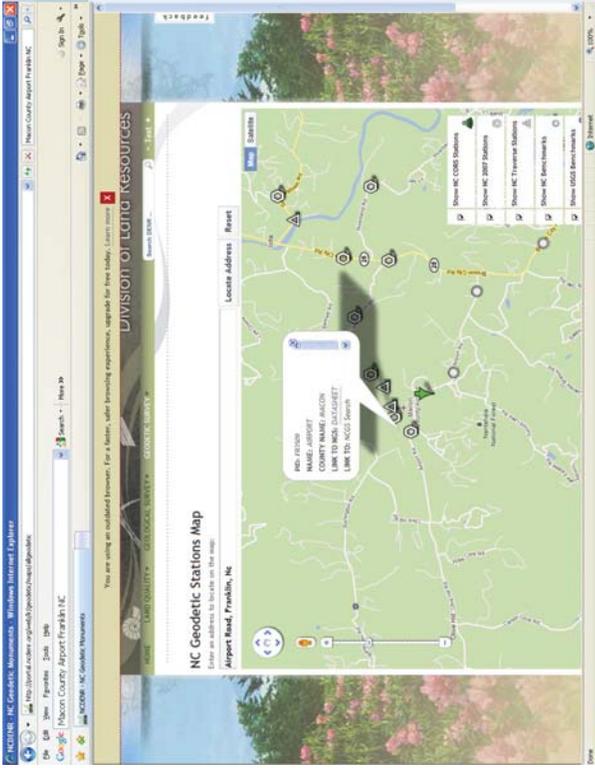


- NCGS has developed a Twitter web page (<http://twitter.com/nctrn>), which is similar to the NCDOT Twitter page (<http://twitter.com/hcdot>)
- Provides information on the status of NC CORS, RTN, and other web features.

# 2012 Coastal Imagery Project







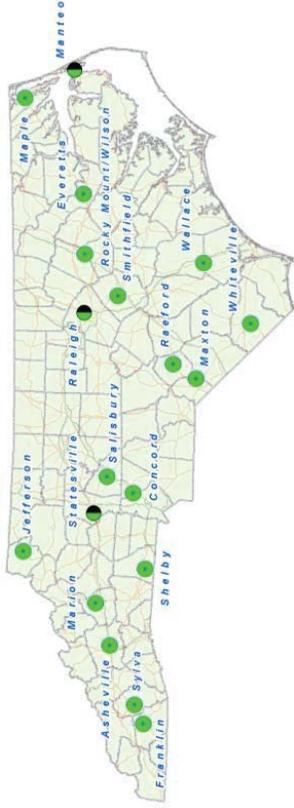
## Stream Gage Surveys

USGS  
Stream  
Gage

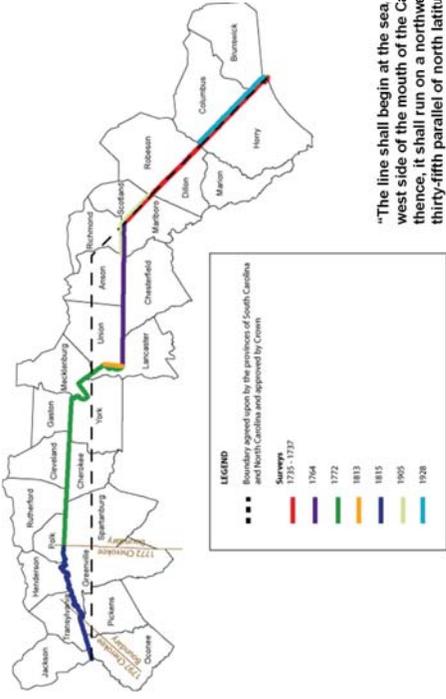


GPS and traditional leveling will be use to connect stream gages to NAVD88

## NC EDM CALIBRATION BASELINES



## NC-SC STATE LINE 1735, 1736, 1737



"The line shall begin at the sea, thirty miles from the west side of the mouth of the Cape Fear River. From thence, it shall run on a northwest course to the thirty-fifth parallel of north latitude, and from thence due west to the South Seas."

## Instructional Videos



## Education Outreach



**Height Modernization Workshops:** is a traveling workshop designed for government agencies, professional surveyors, academic departments, school groups, and other interested parties in North Carolina.

- Workshops are tailored to each group's respective needs
- PDH credit
- Height Modernization Workshops
  - Greenville, NC April 13, 2012
  - Asheville, NC June 15, 2012



## Questions?



Gary Thompson, PLS  
NC Geodetic Survey  
512 North Salisbury Street  
Raleigh, NC 27604  
919-707-9230 phone  
[Gary.thompson@ncdenr.gov](mailto:Gary.thompson@ncdenr.gov)

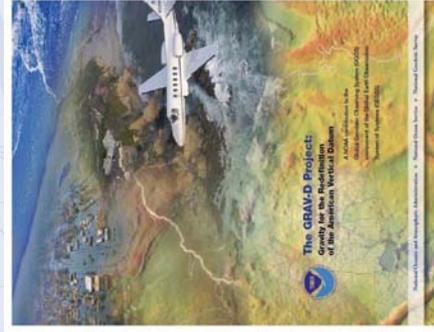
# NGS Gravity for the Redefinition of the American Vertical Datum Project (GRAV-D)

Vicki Childers, Ph.D.  
GRAV-D Project Manager

June 21, 2012

Height Mod Partners Meeting

1



- Replace the Vertical Datum of the USA by 2022 (at today's funding) with a **gravimetric geoid accurate to 1 cm**
- Orthometric heights accessed via GNSS
- Three thrusts of project:
  - Airborne gravity survey of entire country and its holdings
  - Long-term monitoring of geoid change
  - Partnership surveys
- Working to launch a collaborative effort with the USGS for simultaneous magnetic measurement

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## NGS Mission Statement



To define, maintain and provide access to the **National Spatial Reference System** (NSRS) to meet our nation's economic, social, and environmental needs.

The **NSRS** is a consistent coordinate system that defines latitude, longitude, height, scale, gravity, and orientation throughout the United States.

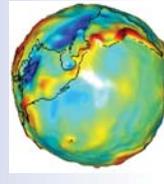
June 21, 2012

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## Building a Gravity Field



Long Wavelengths:  
( $\geq 350$  km)  
[GOCE: ? To 100 km?]

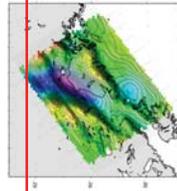


GRACE and GOCE (not shown)



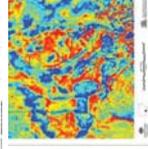
Airborne Measurement

Intermediate Wavelengths  
(500 km to 20 km)



Surface Measurement

Short Wavelengths  
( $< 100$  km)



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4

# GRAV-D Update

## Great Lakes FY11-13



FY10 = Green  
 FY11 = Blue  
 FY12 = Orange  
 FY13 = White

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5

# GRAV-D Update

## Alaska FY 11-13



FY10 = Green  
 FY11 = Blue  
 FY12 = Orange  
 FY13 = White

Height/Mod Partners Meeting

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7

# GRAV-D Update

## Northeastern Seaboard FY12



FY10 = Green  
 FY11 = Blue  
 FY12 = Orange  
 FY13 = White

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6

# GRAV-D Update

## California and Texas



FY10 = Green  
 FY11 = Blue  
 FY12 = Orange  
 FY13 = White

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8

## Geoid Slope Validation Survey

- Proof of concept: Does the addition of the airborne data make for a geoid accurate at 1 cm???

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9



10

Height Mod Partners Meeting  
Gravity gradients

## 2011 Geoid Slope Validation Survey

GPS: 20 identical. units, 10/day leapfrog, 40 hrs ea.

Leveling: 1<sup>st</sup> order, class II, digital barcode leveling

Gravity: FG-5 and A-10 anchors, 4 L/R in 2 teams

DoV: ETH Zurich DIADEM GPS & camera system

LIDAR: Riegl Q680i-D, 2 pt/m<sup>2</sup> spacing, 0.5 km width

Imagery: Applanix 439 RGB DualCam, 5000' AGL

Other:

RTN, short-session GPS, extra gravity marks around Austin, 10 gravity gradients

## 2011 Geoid Slope Validation Survey

- Observe geoid shape (slope) using multiple independent terrestrial survey methods
  - GPS + Leveling
  - Deflections of the Vertical
- Compare **observed** slopes (from terrestrial surveys) to **modeled** slopes (from gravimetry or satellites)
  - With / Without new GRAV-D airborne gravity



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11

## Geoid Slope Survey Conclusions

- Including airborne gravity data improves geoid slope accuracy at nearly all distances <325 km
- The NGS geoid in the TX survey meets the 1 cm accuracy objective only if airborne data are included
  - No other model achieved 1 cm accuracy
- Gravimetric geoid models and GPS are a viable alternative to long-line leveling

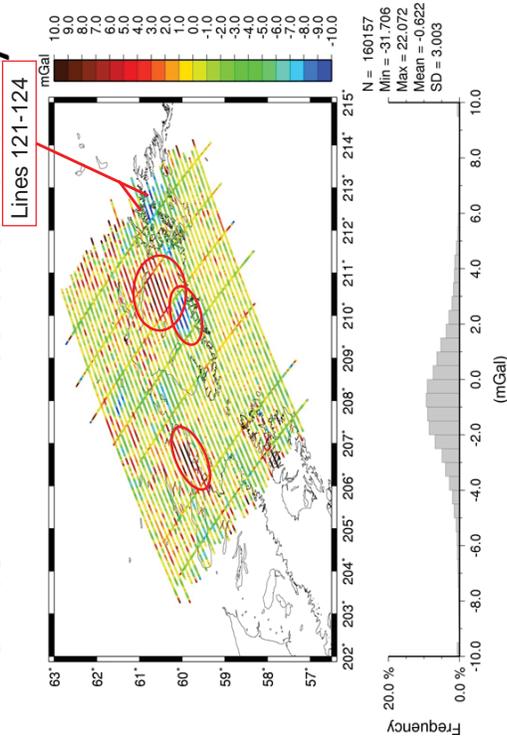
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12

# Questions?

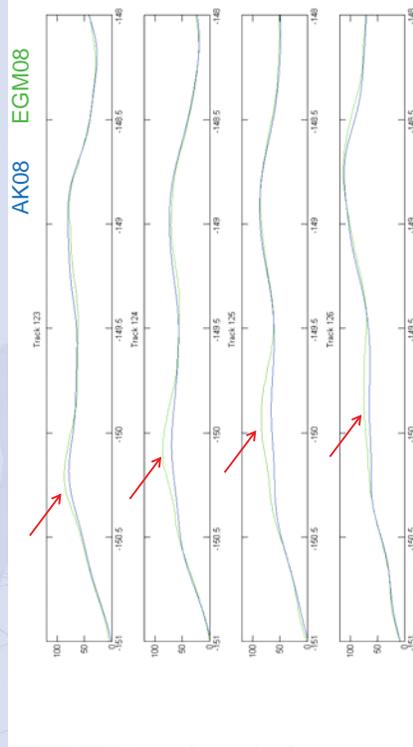
## Newton v1.1 Residual Gravity



# Question

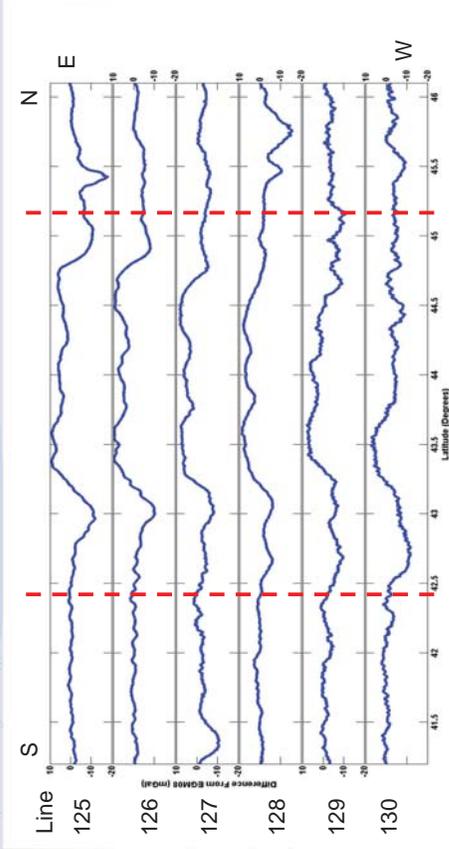
- Can we really create a geoid of sufficient accuracy from this blended gravity field??
- Answer: We'll revisit this...

## AK08 vs. EGM08



Real features that are mis-represented in EGM08 will appear in multiple adjacent airborne data profiles.

# IN11 vs. EGM08 (EGM08 minus IN11)

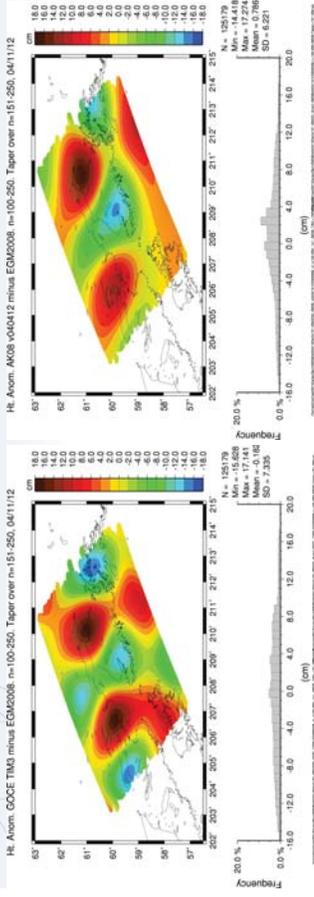


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17

# Residuals with EGM2008

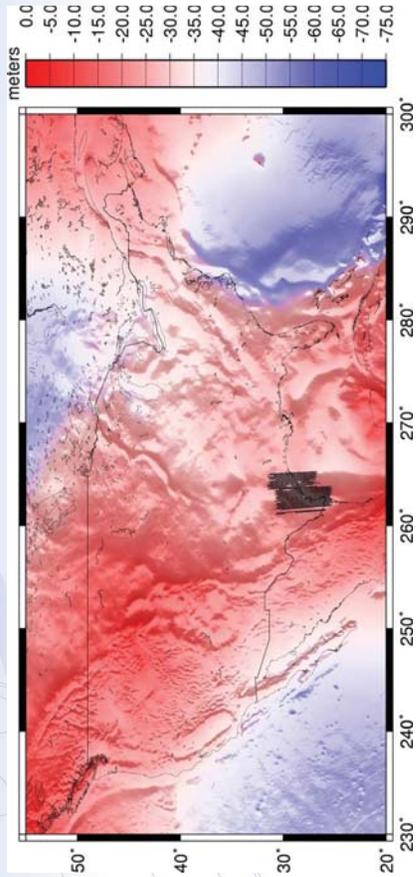


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18

# EGM08 Geoid

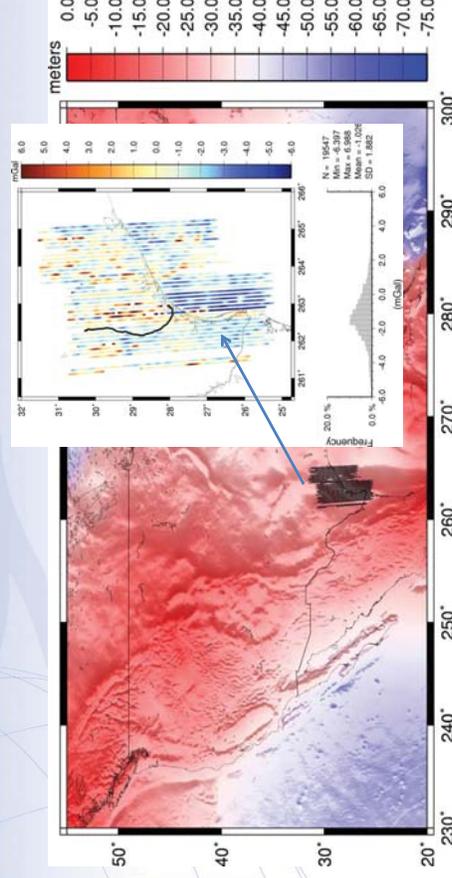


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19

# EGM08 Geoid

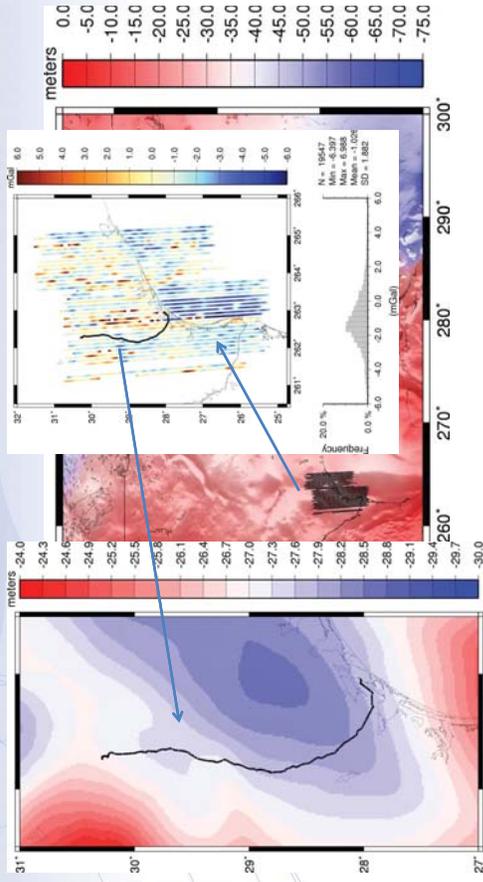


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20

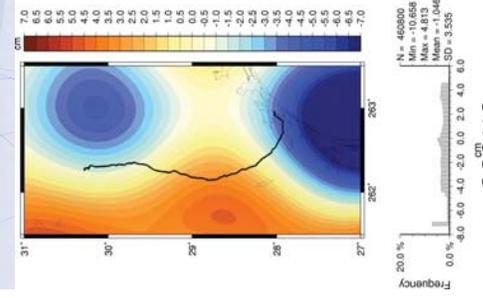
# EGM08 Geoid



June 2, 2008  
Blow up of EGM08 Geoid over GSYS area

Height Mod Partners Meeting

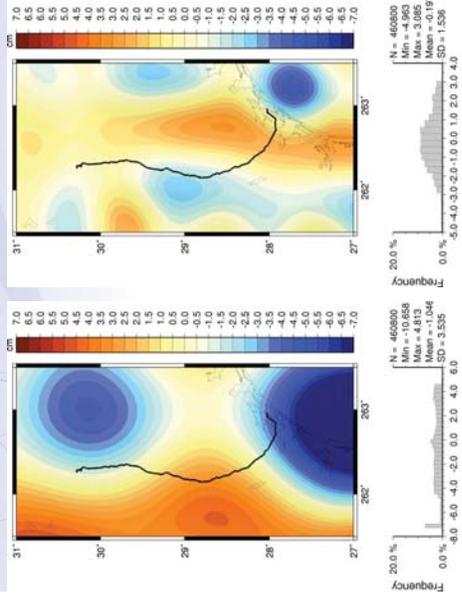
# Updates to EGM2008: New Data



June 21, 2008  
GOC02S

Height Mod Partners Meeting

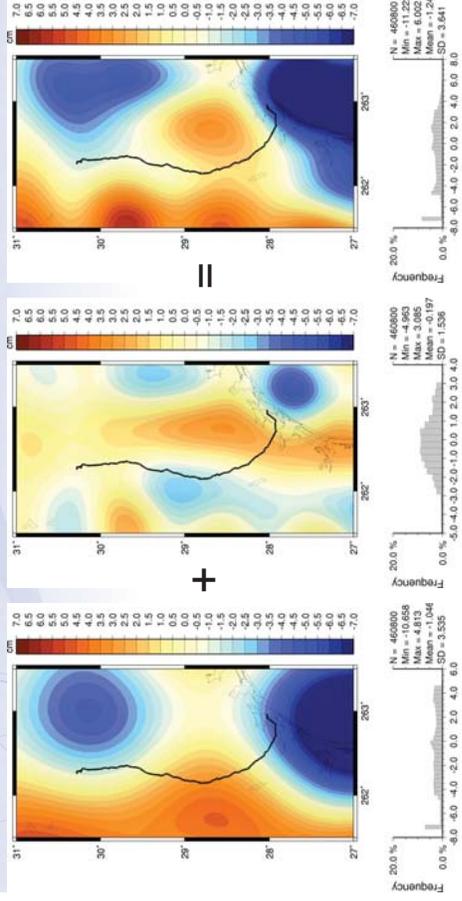
# Updates to EGM2008: New Data



June 21, 2008  
GOC02S

Height Mod Partners Meeting

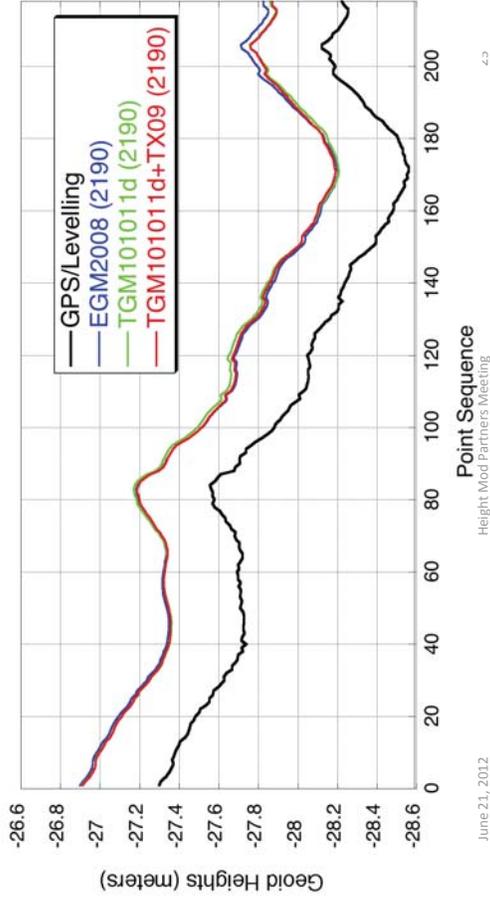
# Updates to EGM2008: New Data



June 21, 2008  
GOC02S

Height Mod Partners Meeting

## Profiles along GSVS Line

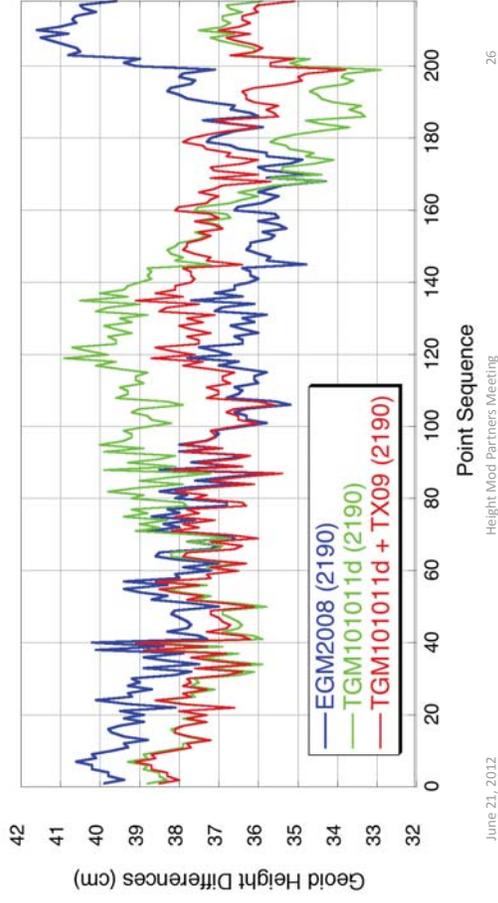


June 21, 2012

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26

## Models Differenced with GPS Leveling

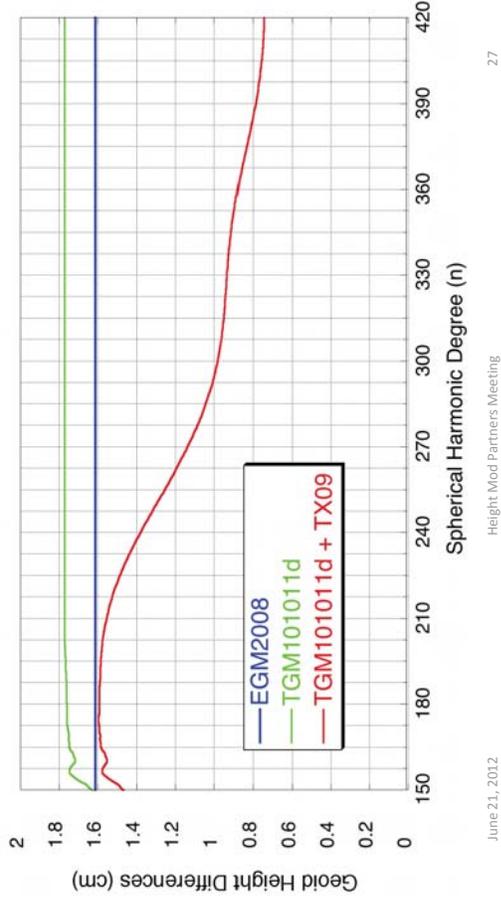


June 21, 2012

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26

## Standard Dev Of Blended Models wrt GPS Level Data

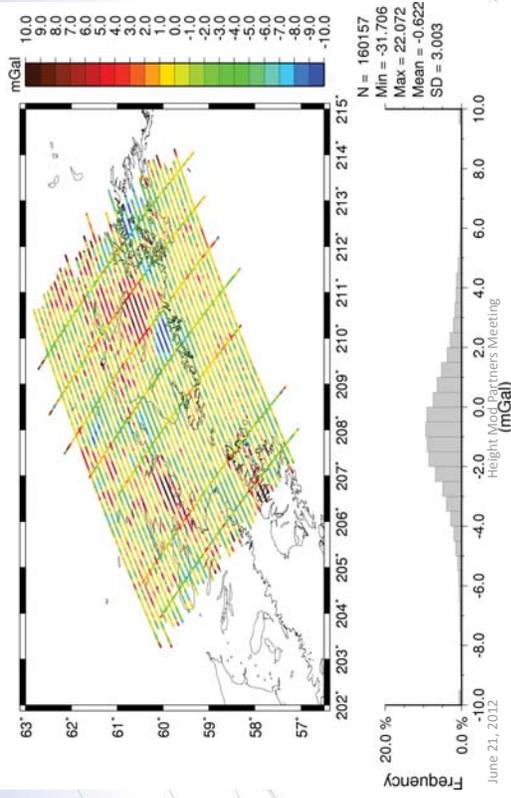


June 21, 2012

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27

RESIDUALS, dg\_AK08\_v121010\_v44\_3\_12/10/10

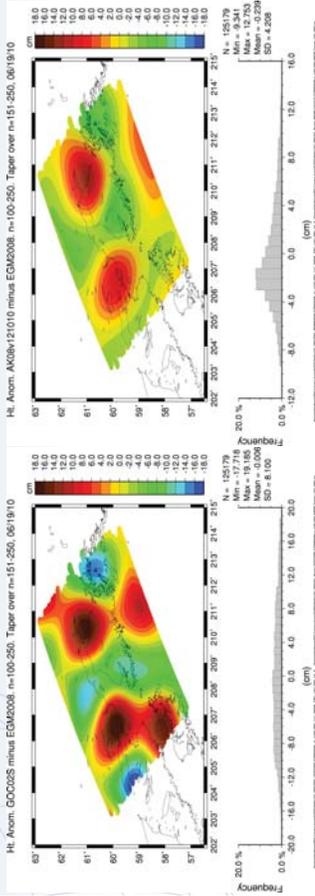


June 21, 2012

Height Mod Partners Meeting

28

# Residuals with EGM2008



June 21, 2012

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29

- NOAA
  - Gulfstream Jet Prop
  - NOAA P-3 Hurricane Hunter
- DOI Bureau of Land Management
  - Pilatus PC-12
- Fugro
  - King Air E-90A
- Naval Research Lab
  - King Air RC-12

June 21, 2012

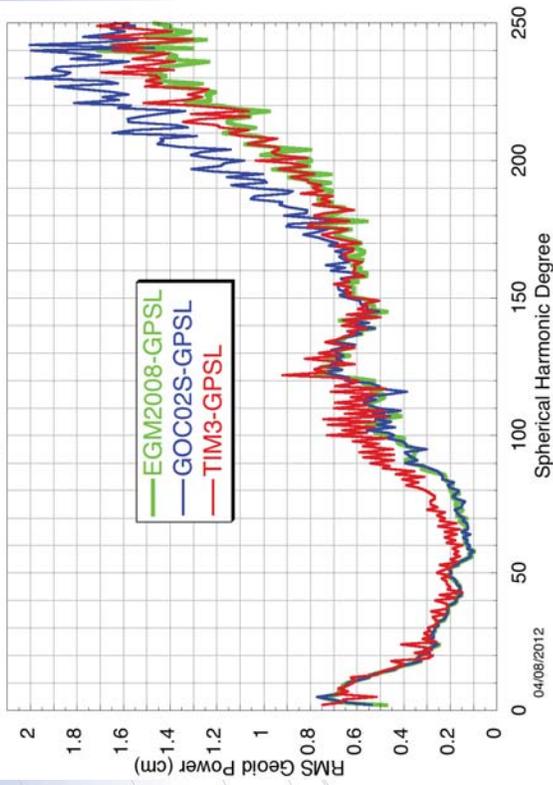
Height Mod Partners Meeting

King Air E-90A<sup>30</sup>



# GRAV-D Aircraft

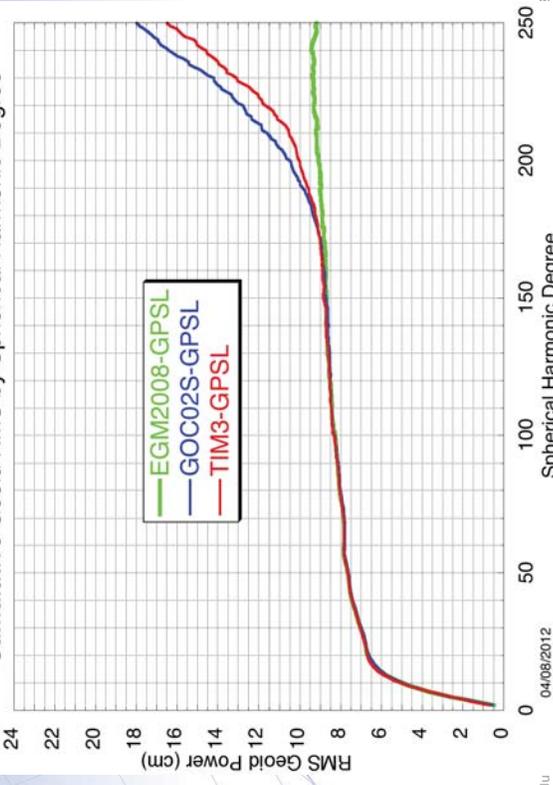
# TIM3/GOC02S/EGM2008 vs GPSL over CONUS Geoid RMS by Spherical Harmonic Degree



04/08/2012

31

# TIM3/GOC02S/EGM2008 vs GPSL over CONUS Cumulative Geoid RMS by Spherical Harmonic Degree



04/08/2012



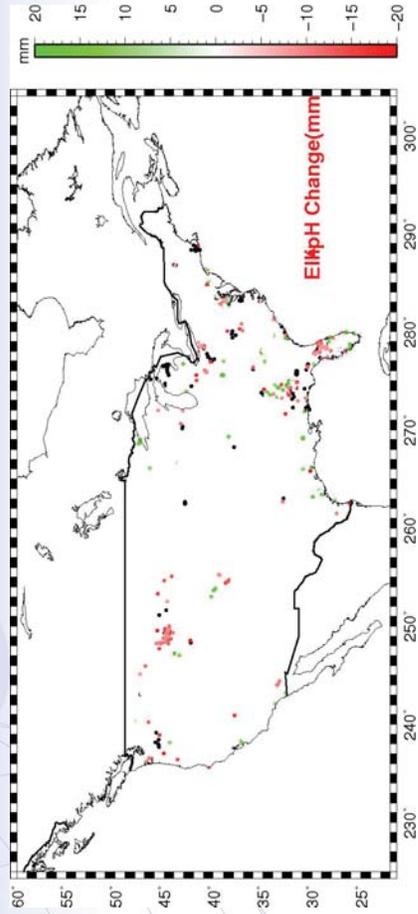
# GEOID12 and Related Models

21 JUN 2012 Update

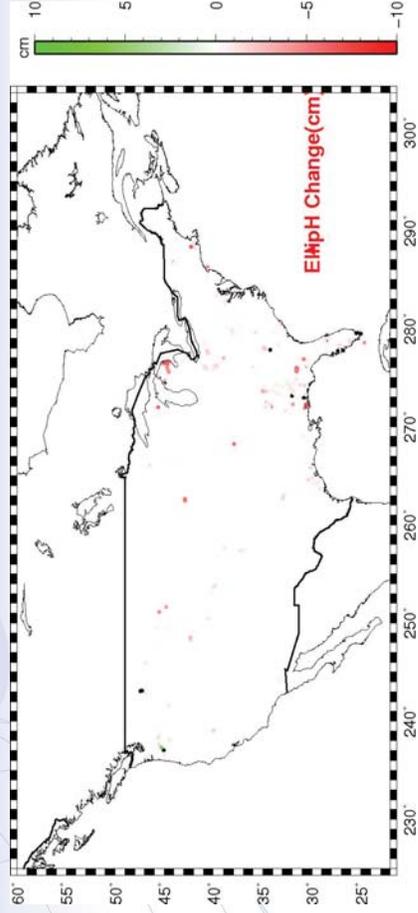
# 2009 to 2012 Comparisons

Geoid12	Geoid09	BP	NP	NS	BS	NULL
BP		442 (AA11) Change Range [-0.071 min 0.030 max]	16669(AA12) ) [-0.338 0.288]	42(AA13) [0.000 0.066]	1 (AA14) -0.284 1010 726	3167(AA15) [-0.061 0.087]
NP		1431(AA21) [-0.040 0.005]	177(AA22) [-0.004 0.005]	2(AA23) -0.0040 -0.004	15(AA24) [-0.271 0.171]	29(AA25) [-0.004 0.005]
NS		33 (AA31) [-0.004 0.005]	2(AA32) [-0.047 0.001]	3 (AA33) [-0.140 0.002]	105 (AA34) [-0.004 0.005]	0 (AA35)
BS		11 (AA41) [-0.039 0.208]	112 (AA42) [0.00 0.039]	770(AA43) [-0.005 0.405]	3(AA44) [0.00 0.006]	6 (AA45) [0.000 0.021]
NULL		0	0	0	0	0

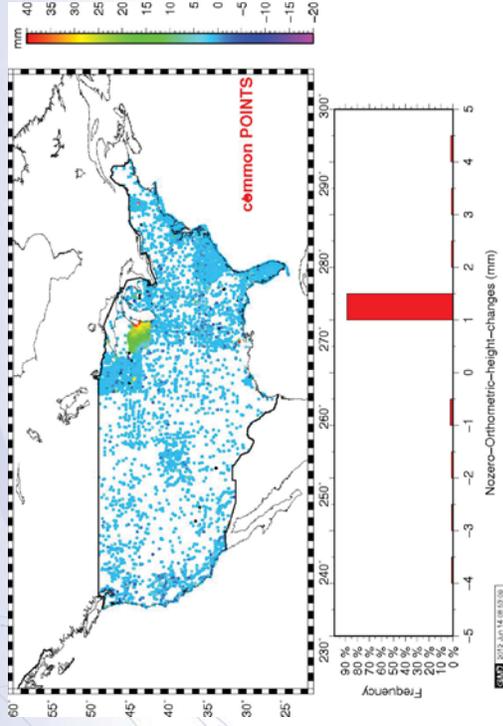
# Ellipsoidal Height Changes (mm)



# Ellipsoidal Height Changes (cm)



## Orthometric Height Changes



## Status on Production

- USGG2012: on Beta website ready for upload
- GEOID12: In Progress with RTL on 23 June
- USDV2012: Not started (mid-July)
- DEFLEC12: Not started (mid-July)
- GEOID12 error map: Not Started (mid-July)
- GPSBM2012 Data Density Map: Not Started (mid-July)

## June Production Timeline

14: send to Advisers Plus for review and confirmation on selections for rejection - mainly for CONUS but also for Alaska

14: finish validating changes in leveling heights from GPSBM2009 to recent datasheet pull

14-15: receive OPUS-DB input from Joe Evjen

14-15: receive culled set of data for Gulf Coast subsidence states from Renee and Dave Z.

15: start preliminary modeling to rough math model for CONUS and AK based on semi-final list, OPUS-DB and Gulf-Coast mods

15-17: develop models for Guam, CNMI, American Samoa => send to Sri/Brian for test webpage

18: modify LSC modeling program to output variances to predict error grid

19-20: finish validating grids and put them up on web - should include Guam/CNMI, PR/VI, American Samoa, and Hawaii.

19-20: Brian and Sri ensure that webpages are active and load available grids; develop text for webpages

21: received \*final\* inputs from state advisers

21-22: incorporate final changes and make final GPSBM2012 for Alaska and CONUS

21-22: develop GEOID12 for CONUS and Alaska

23-30: load final models onto website and QA links into other programs (datasheet95, OPUS, etc.)

23-30: finalize most text for websites