

NATIONAL GEODETIC SURVEY

# Geoid Height Models at NGS

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## OUTLINE

- The GEOID team
- What we produce
- Next models
- Ongoing research
- The future



## The Geoid Team

- Primary Researchers
  - Daniel Roman, Ph.D.
  - Yan Ming Wang, Ph.D.
- Support
  - Gravity database & analysis: Jarir Saleh
  - Software & database: William Waickman



## What We Produce: Geoid Height Models

- Q: So *what's* a "geoid height" model?
- A: A model of the separation between a geoid or vertical datum and an ellipsoidal datum.
- Q: The separation between a *what* and a *what*?!?
- A: OK ... maybe a brief GEOID 101 tutorial to cover the basics ...



# Global Relationships Between Geodetic Surfaces/Datums

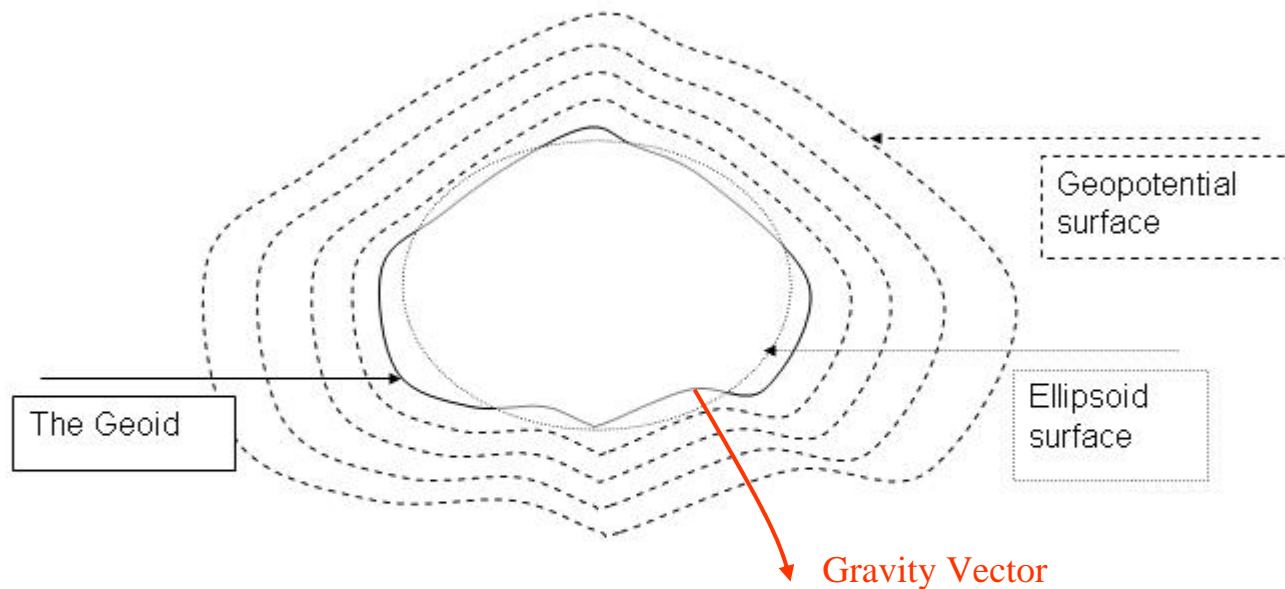


Figure 1. The relationships between the ellipsoid surface (dotted), various geopotential surfaces (dashed) and the geoid (solid). The geoid exists approximately at mean sea level (MSL). Not shown is the actual surface of the Earth, which coincides with MSL but is generally above the geoid.

$$h = H + N$$

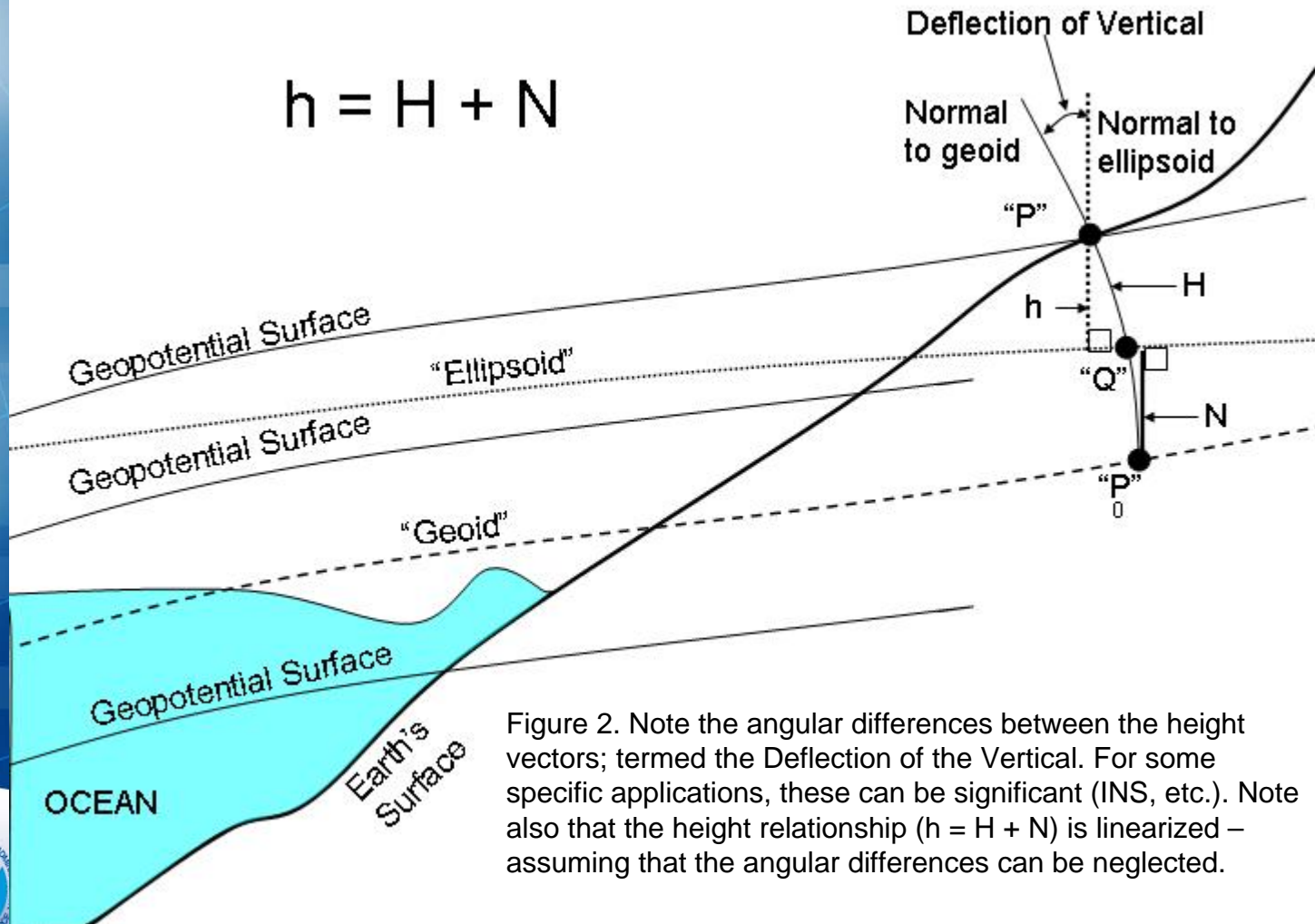
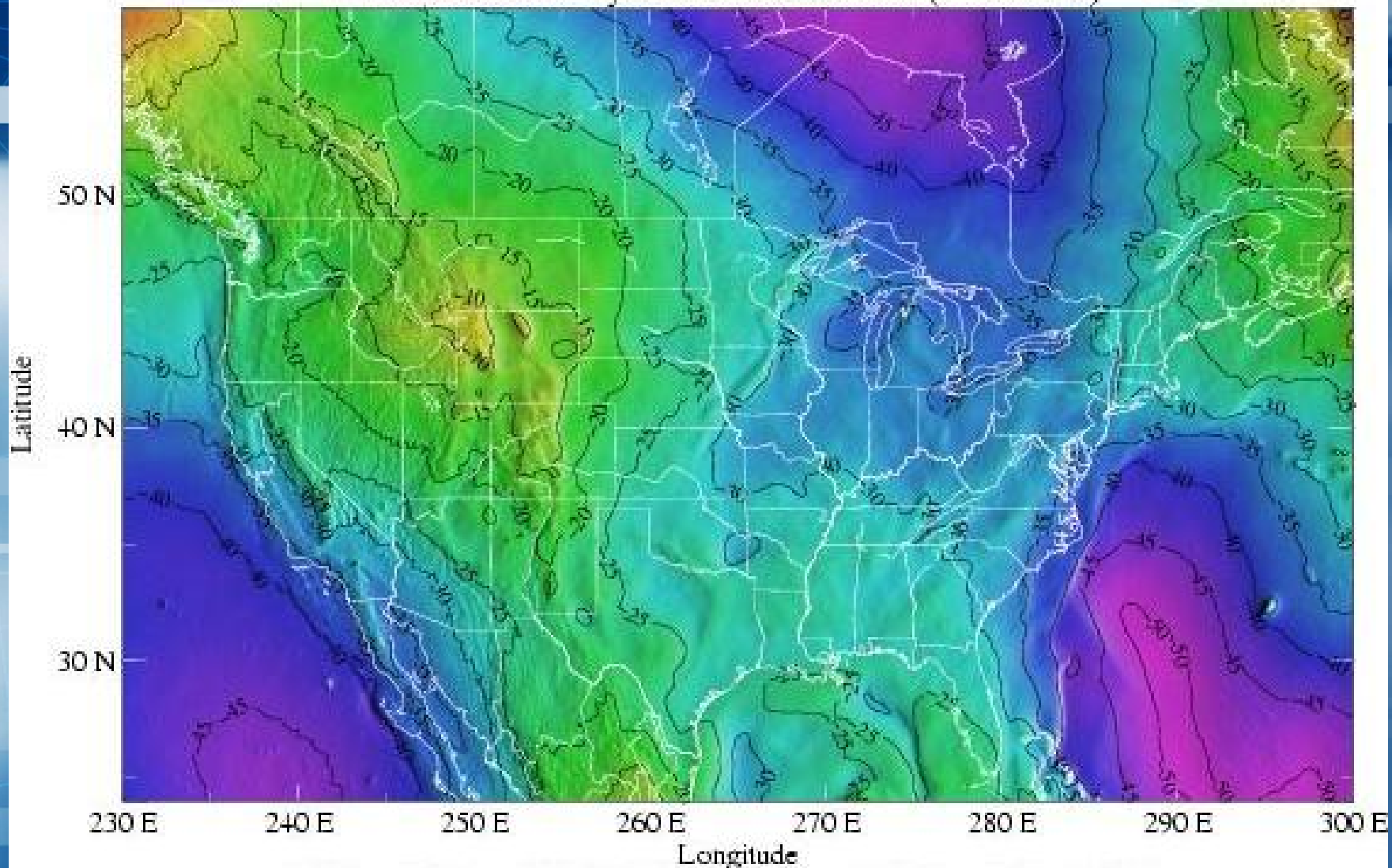


Figure 2. Note the angular differences between the height vectors; termed the Deflection of the Vertical. For some specific applications, these can be significant (INS, etc.). Note also that the height relationship ( $h = H + N$ ) is linearized – assuming that the angular differences can be neglected.

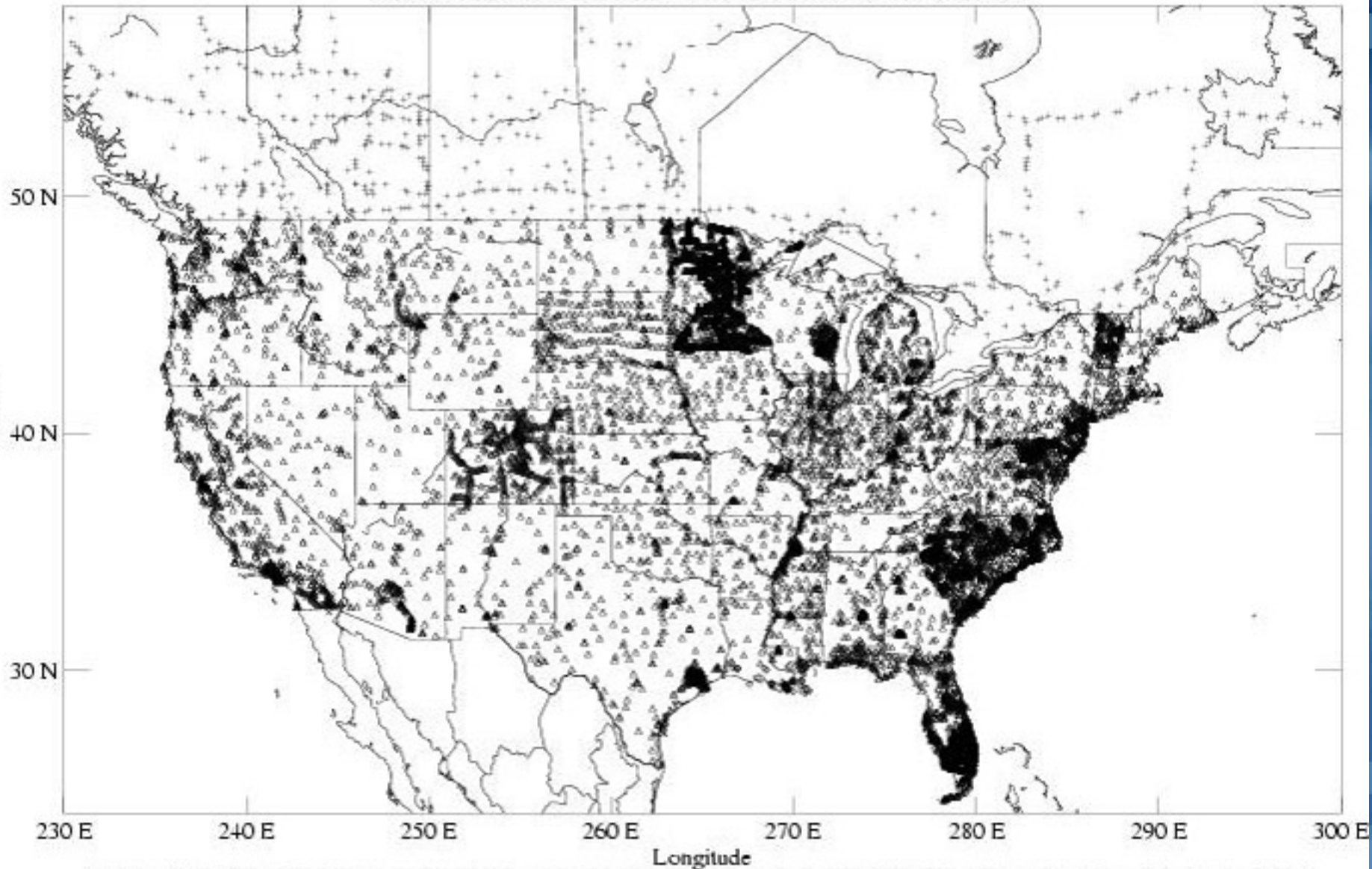
# United States Hybrid Geoid for 2003 (GEOID03)



MIN = -51.009 m MAX = 3.428 m AVE = -29.488 m STD = 10.106 m



### 2003 GPSBM Control Data Used to Create GEOLD03



14308 total: 13554 NGS database (triangles) + 52 mod. S. Louisiana (diamonds) + 579 Canadian (plusses) + 123 rejected (X's)



<b>GEOID and DEFLECTION models at NGS</b>								
	CONUS	Alaska	Hawaii	Puerto Rico and the American Virgin Islands	Mexico	Caribbean Sea	Guam	American Samoa
<b>HYBRID GEOID MODELS</b>	<a href="#"><u>GEOID03</u></a> <a href="#"><u>GEOID99</u></a> <a href="#"><u>G99BM</u></a> <a href="#"><u>GEOID96</u></a>	None Exist	None Exist	None Exist	None Exist	None Exist	None Exist	None Exist
<b>GRAVIMETRIC GEOID MODELS</b>	<a href="#"><u>USGG2003</u></a> <a href="#"><u>G99SSS</u></a> <a href="#"><u>G96SSS</u></a> <a href="#"><u>GEOID93</u></a> <a href="#"><u>GEOID90</u></a>	<a href="#"><u>GEOID99</u></a> <a href="#"><u>GEOID96</u></a> <a href="#"><u>ALASKA94</u></a>	<a href="#"><u>GEOID99</u></a> <a href="#"><u>GEOID96</u></a> <a href="#"><u>GEOID93</u></a>	<a href="#"><u>GEOID99</u></a> <a href="#"><u>GEOID96</u></a> <a href="#"><u>GEOID93</u></a>	<a href="#"><u>MEXICO97</u></a>	<a href="#"><u>CARIB97</u></a>	None Exist	None Exist
<b>HYBRID DEFLECTION OF THE VERTICAL MODELS</b>	<a href="#"><u>DEFLEC99</u></a> <a href="#"><u>DEFLEC96</u></a>	None Exist	None Exist	None Exist	None Exist	None Exist	None Exist	None Exist
<b>GRAVIMETRIC DEFLECTION OF THE VERTICAL MODELS</b>	<a href="#"><u>DEFLEC93</u></a> <a href="#"><u>DEFLEC90</u></a>	<a href="#"><u>DEFLEC99</u></a> <a href="#"><u>DEFLEC96</u></a> <a href="#"><u>DALASKA94</u></a>	<a href="#"><u>DEFLEC99</u></a> <a href="#"><u>DEFLEC96</u></a> <a href="#"><u>DEFLEC93</u></a>	<a href="#"><u>DEFLEC99</u></a> <a href="#"><u>DEFLEC96</u></a> <a href="#"><u>DEFLEC93</u></a>	<a href="#"><u>DMEX97</u></a>	<a href="#"><u>DCAR97</u></a>	None Exist	None Exist



## GEOID HEIGHT and DEFLECTION models at NGS

	CONUS	Alaska	Hawaii	Puerto Rico and the American Virgin Islands	Mexico	Caribbean Sea	Guam	American Samoa
<b>HYBRID GEOID MODELS (defined by NAVD 88, PRVD 02, GUVD 04, ASVD 02, or other local vertical datums)</b>								
Reference Ellipsoid geocenter is defined by NAD 83	<a href="#">GEOID03</a>  <a href="#">GEOID99</a> <a href="#">GEOID96</a>	<a href="#">GEOID06</a>	None Exist	<a href="#">GEOID06</a>	None Exist	None Exist	None Exist	None Exist
Reference Ellipsoid geocenter is defined by ITRF	<a href="#">G99BM</a>	None Exist	None Exist	None Exist	None Exist	None Exist	None Exist	None Exist
<b>GRAVIMETRIC GEOID MODELS (defined by a Wo value derived from a global reference gravity field model such as EGM96)</b>								
Reference Ellipsoid is NAD 83	None Exist	<a href="#">GEOID03</a>	<a href="#">GEOID03</a>	<a href="#">GEOID03</a>	None Exist	None Exist	<a href="#">GEOID03</a>	<a href="#">GEOID03</a>
Reference Ellipsoid is derived from ITRF series	<a href="#">USGG2003</a>  <a href="#">G99SSS</a> <a href="#">G96SSS</a> <a href="#">GEOID93</a> <a href="#">GEOID90</a>	<a href="#">USGG2003</a>  <a href="#">GEOID99</a> <a href="#">GEOID96</a> <a href="#">ALASKA94</a>	<a href="#">USGG2003</a>  <a href="#">GEOID99</a> <a href="#">GEOID96</a> <a href="#">GEOID93</a>	<a href="#">USGG2003</a>  <a href="#">GEOID99</a> <a href="#">GEOID96</a> <a href="#">GEOID93</a>	<a href="#">GGM05</a>  <a href="#">GGM04</a> <a href="#">MEXICO97</a>	<a href="#">CARIB97</a>	None Exist	None Exist
HYBRID DEFLECTION OF THE VERTICAL MODELS	<a href="#">DEFLEC99</a>  <a href="#">DEFLEC96</a>	None Exist	None Exist	None Exist	None Exist	None Exist	None Exist	None Exist
GRAVIMETRIC DEFLECTION OF THE VERTICAL MODELS	<a href="#">DEFLEC93</a> <a href="#">DEFLEC90</a>	<a href="#">DEFLEC99</a>  <a href="#">DEFLEC96</a> <a href="#">DALASKA94</a>	<a href="#">DEFLEC99</a>  <a href="#">DEFLEC96</a> <a href="#">DEFLEC93</a>	<a href="#">DEFLEC99</a>  <a href="#">DEFLEC96</a> <a href="#">DEFLEC93</a>	<a href="#">DMEX97</a>	<a href="#">DCAR97</a>	None Exist	None Exist



## What else is produced?

- Deflection of the Vertical
  - Derived from geoid height model
  - Angle between normals to ellipsoid & geoid
  - Useful in navigation functions
- Surface Gravity Interpolation
  - Provides a point estimate of surface gravity
  - Used in sensitive engineering applications
  - Also used in some scientific studies of tides



# GEOID HEIGHT and DEFLECTION models at NGS

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<b>HYBRID GEOID MODELS (defined by NAVD 88, PRVD 02, GUVD 04, ASVD 02, or other local vertical datums)</b>								
<b>Reference Ellipsoid geocenter is defined by NAD 83</b>	<a href="#">GEOID06</a> <a href="#">GEOID03</a> <a href="#">GEOID99</a> <a href="#">GEOID96</a>	<a href="#">GEOID06</a>	<a href="#">GEOID06</a>	<a href="#">GEOID06</a>	<a href="#">GEOID06</a>	<a href="#">GEOID06</a>	<a href="#">GEOID06</a>	<a href="#">GEOID06</a>
<b>Reference Ellipsoid geocenter is defined by ITRF</b>	<a href="#">G99BM</a>	None Exist	None Exist	None Exist	None Exist	None Exist	None Exist	None Exist
<b>GRAVIMETRIC GEOID MODELS (defined by a <math>W_0</math> value derived from a global reference gravity field model such as EGM96)</b>								
<b>Reference Ellipsoid is NAD 83</b>	None Exist	<a href="#">GEOID03</a>	<a href="#">GEOID03</a>	<a href="#">GEOID03</a>	None Exist	None Exist	<a href="#">GEOID03</a>	<a href="#">GEOID03</a>
<b>Reference Ellipsoid is derived from ITRF series</b>	<a href="#">USGG2006</a> <a href="#">USGG2003</a> <a href="#">G99SSS</a> <a href="#">G96SSS</a> <a href="#">GEOID93</a> <a href="#">GEOID90</a>	<a href="#">USGG2006</a> <a href="#">USGG2003</a> <a href="#">GEOID99</a> <a href="#">GEOID96</a> <a href="#">ALASKA94</a>	<a href="#">USGG2006</a> <a href="#">USGG2006</a> <a href="#">GEOID99</a> <a href="#">GEOID96</a> <a href="#">GEOID93</a>	<a href="#">USGG2006</a> <a href="#">USGG2003</a> <a href="#">GEOID99</a> <a href="#">GEOID96</a> <a href="#">GEOID93</a>	<a href="#">GGM05</a> <a href="#">GGM04</a> <a href="#">MEXICO97</a>	<a href="#">CARIB97</a>	<a href="#">USGG2006</a>	<a href="#">USGG2006</a>
<b>HYBRID DEFLECTION OF THE VERTICAL MODELS</b>	<a href="#">DEFLEC06</a> <a href="#">DEFLEC99</a> <a href="#">DEFLEC96</a>	<a href="#">DEFLEC06</a>	<a href="#">DEFLEC06</a>	<a href="#">DEFLEC06</a>	None Exist	None Exist	<a href="#">DEFLEC06</a>	<a href="#">DEFLEC06</a>
<b>GRAVIMETRIC DEFLECTION OF THE VERTICAL MODELS</b>	<a href="#">DEFLEC93</a> <a href="#">DEFLEC90</a>	<a href="#">DEFLEC99</a> <a href="#">DEFLEC96</a> <a href="#">DALASKA94</a>	<a href="#">DEFLEC99</a> <a href="#">DEFLEC96</a> <a href="#">DEFLEC93</a>	<a href="#">DEFLEC99</a> <a href="#">DEFLEC96</a> <a href="#">DEFLEC93</a>	<a href="#">DMEX97</a>	<a href="#">DCAR97</a>	None Exist	None Exist

## Models Under Development

- GEOID06: CONUS, PR/VI
  - CONUS data reflect pre-NRA solution
  - Pull complete: nearly 18,000 points
  - PR/VI will be tied to PRVD 02 model (hybrid)
- USGG2006: CONUS
  - Validation of reference field used (GRACE)
  - Already see a half cm improvement nationally when comparing to the GPSBM's
  - Incorporation of coastal aerogravity study
  - Comparison at tide gauges and with VDatum



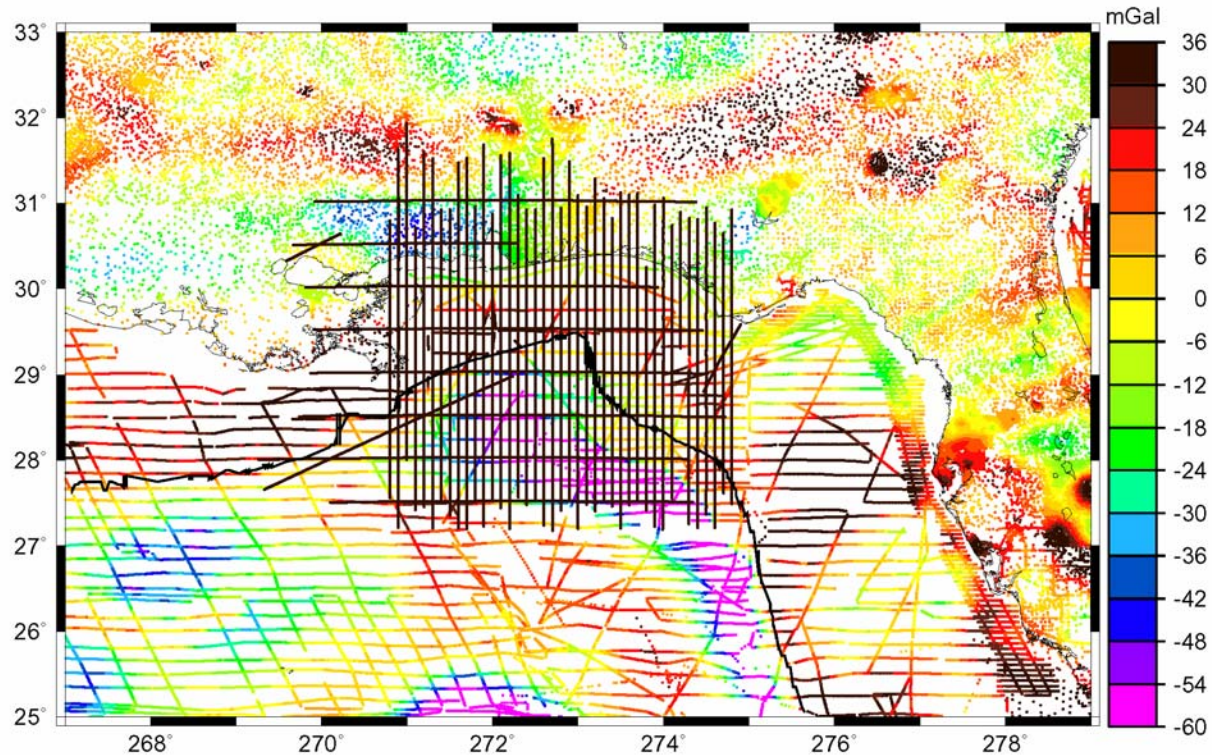
## Near Term Research

- Assessing impact of aerogravity in coastal regions
- Utility of GPS/INS vs. aerogravity for gravity
- Assessment of EGM06 and GRACE-based gravity
- Temporal effects in gravity and geoid
- Seamless & accurate gravity data set
- Improved theory for determining geoid height models from gravity data
- Monte Carlo study of current gravimetric geoid height model
- Error propagation to estimate hybrid geoid errors

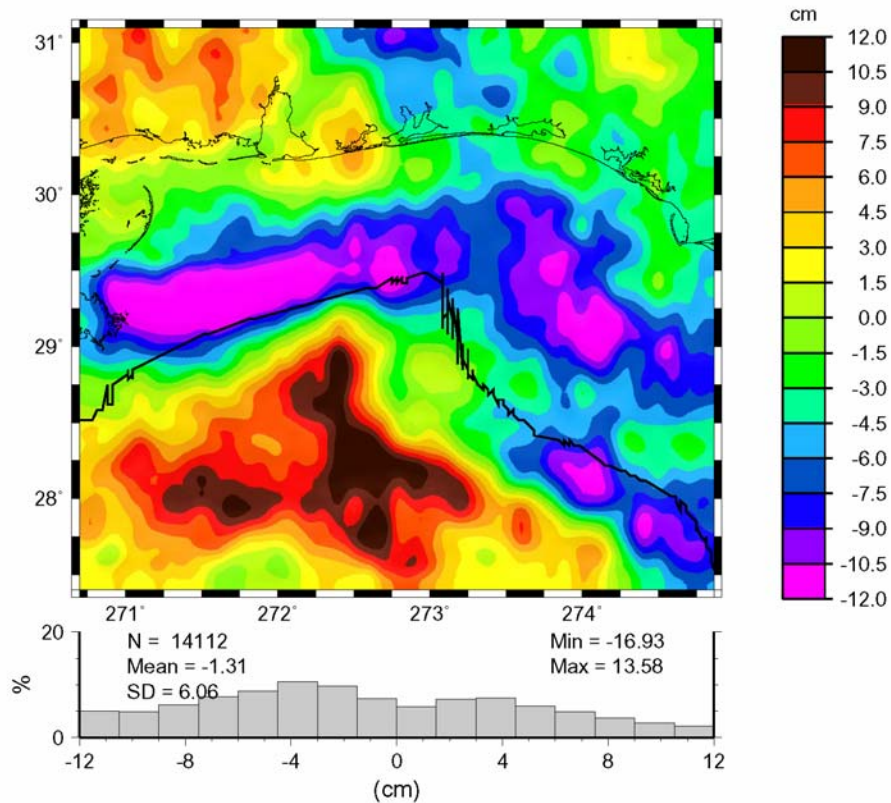


# Extent of Gravity and Data Collection Flights

Airborne Tracks and NGS Database Gravity Anomalies Over the Gulf of Mexico



# Equivalent Pseudo-Geoid Signal for 91s Filter





## Long Term Goals

- Orthometric heights determined from a cm-level accurate gravimetric geoid applied to cm-level accurate GPS-derived ellipsoidal heights
- An error model of the existing NAVD 88 datum
- A unifying datum common to all interested countries in the hemisphere (Canada, Mexico, other North & Central American countries, and Caribbean nations).
- A common basis for an IGLD15 model



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QUESTIONS?



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