National Geodetic Survey

GRAV-D

Gravity for the Re-definition of the American Vertical Datum

National Oceanic and Atmospheric Administration

Why this briefing?

- NGS recently acquired a new airborne gravimeter
  - Intended to support **GRAV-D**
- **GRAV-D** is an ambitious new plan for NGS to accomplish part of its mission
  - Up front costs
  - Long-term savings
  - A huge contribution to GEOSS
  - Part of the NGS, NOS and NOAA missions

Q: What is GRAV-D?

A: Gravity to *determine heights* accurately

- The first, middle and last point of GRAV-D:

Gravity *and* ***Heights*** *are inseparably connected*

- *Or (to borrow from a common bumper sticker):*
  - *No gravity, no height*
  - *Know gravity, know height*

Dominant Height Systems in use in the USA

Requires Gravity

- **Orthometric**
  - Colloquially, but incorrectly, called "height above mean sea level"
  - On most topographic maps
  - Is a >99% successful method to tell which way water will flow

- **Ellipsoid**
  - Almost exclusively from GPS
  - Won't tell water flow / floodplains

Requires Gravity

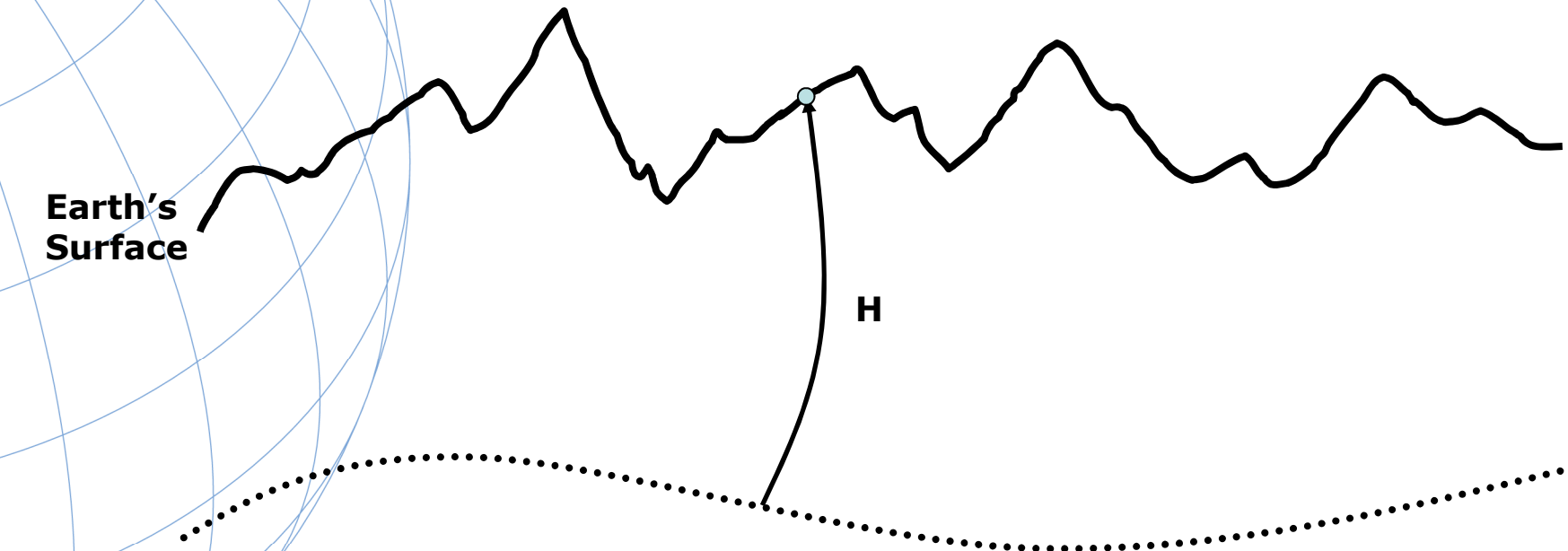
- **Dynamic**
  - Directly proportional to potential *energy* : always tells which way water will flow
  - Dynamic heights are *not* lengths!
  - More on this later…

Heights

- Most heights need to refer to some "reference surface"
- The reference surface is part of the "vertical datum"

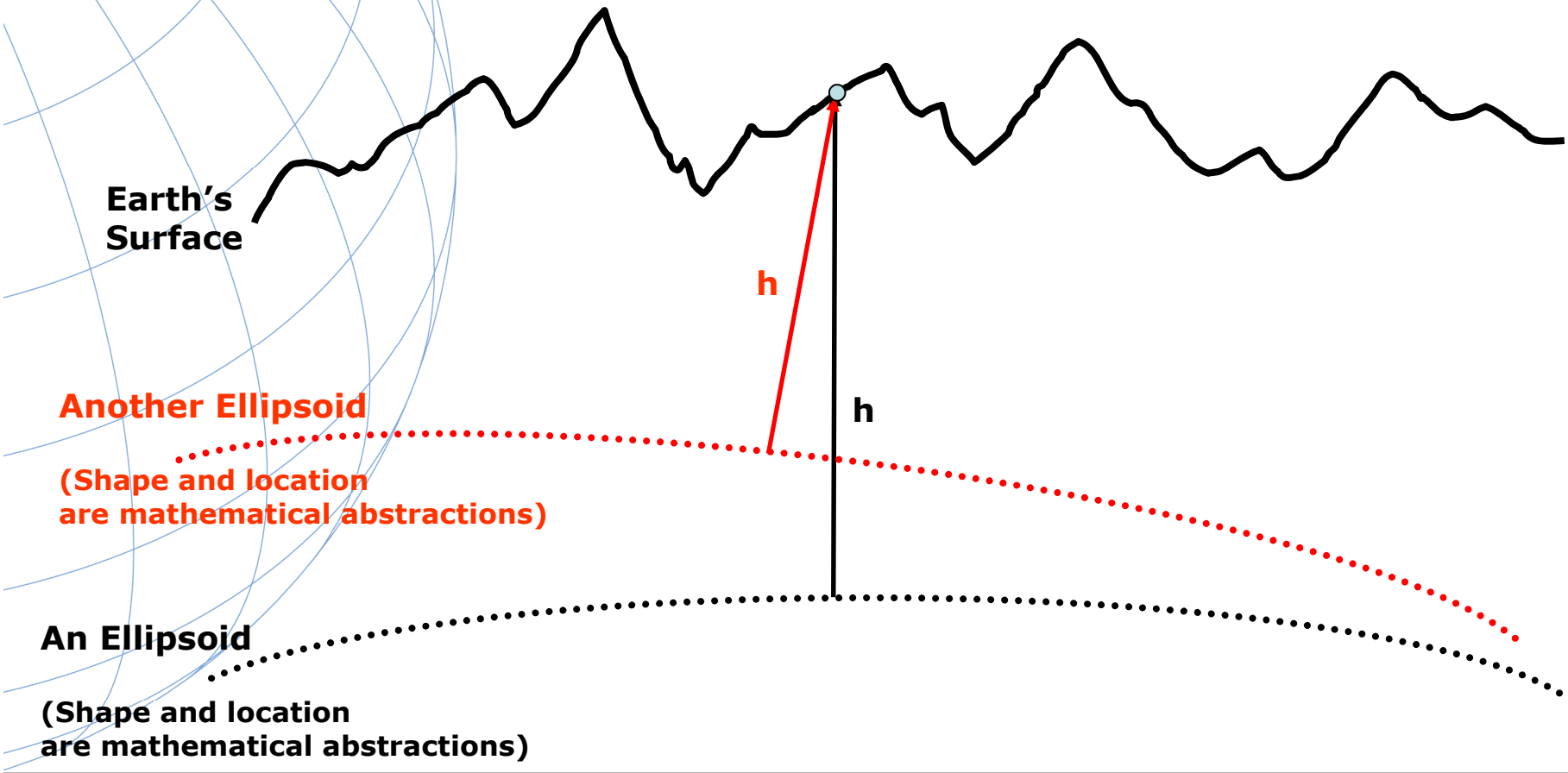
Orthometric Height (H)

- The distance along the *plumb line* from *the geoid* up to the point of interest



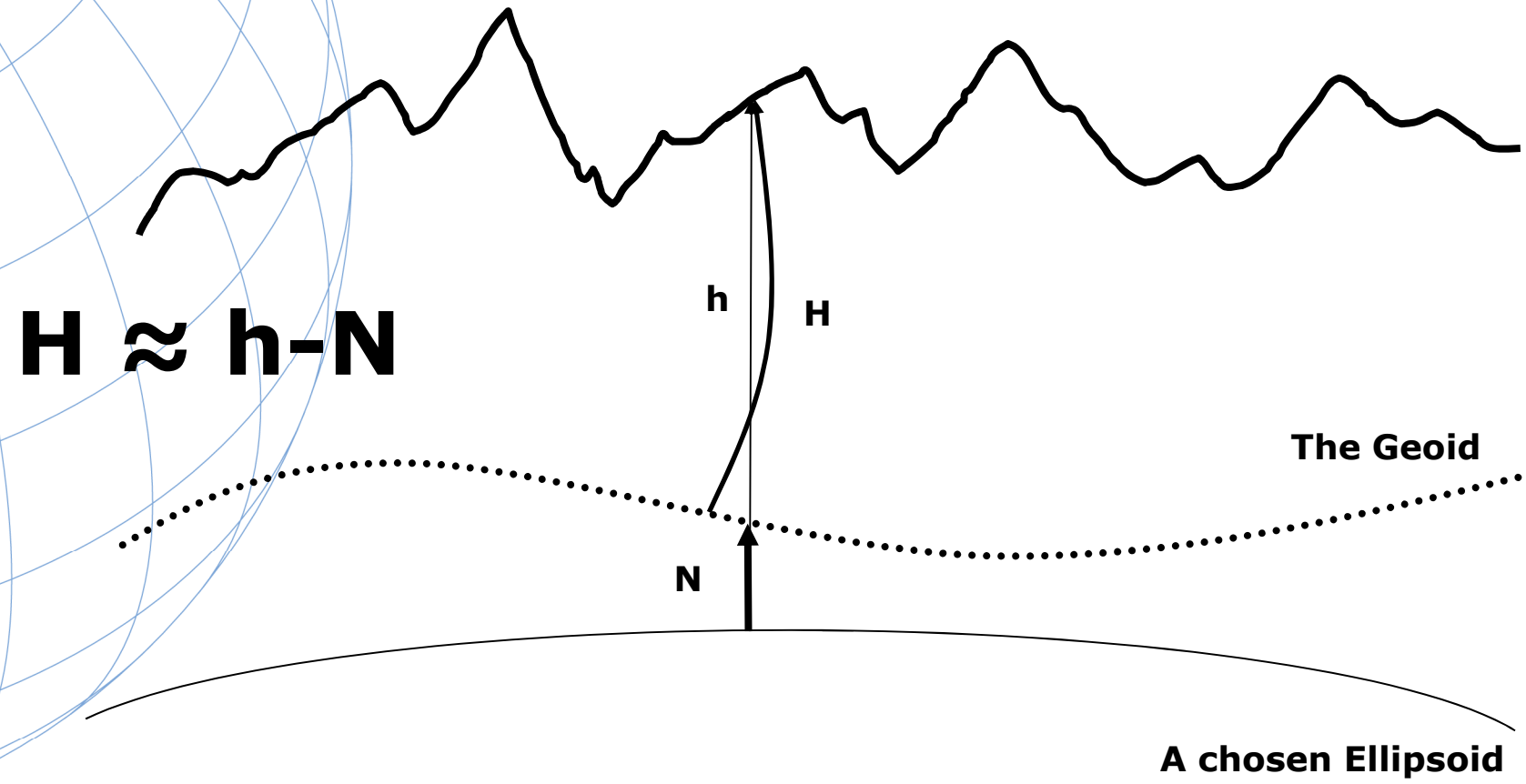
Ellipsoid Height (h)

- The distance along the *ellipsoidal normal* from *some ellipsoid* up to the point of interest



Geoid Undulation (N)

- The distance along the *ellipsoidal normal* from *some ellipsoid* up to *the geoid*



Vertical Datums in the USA

- Ellipsoid heights: NAD 83
- Orthometric heights: NAVD 88

Vertical Datum – History (Orthometric Heights)

- 1807 – 1996
  - Defined and Accessed – Leveling/Passive Marks
  - NAVD 88: 600,000+ Marks
    - NGS detects hundreds moved/destroyed every year
    - How many go undetected?
      - Post-Glacial-Rebound, Subsidence, Tectonics, Frost-Heave – lots of motion out there!

Leveling to define and use NAVD 88

- Leveling
  - Measure geometric changes point to point
  - Correct for multiple physical effects
  - Attempts to yield differential geopotential (energy) levels

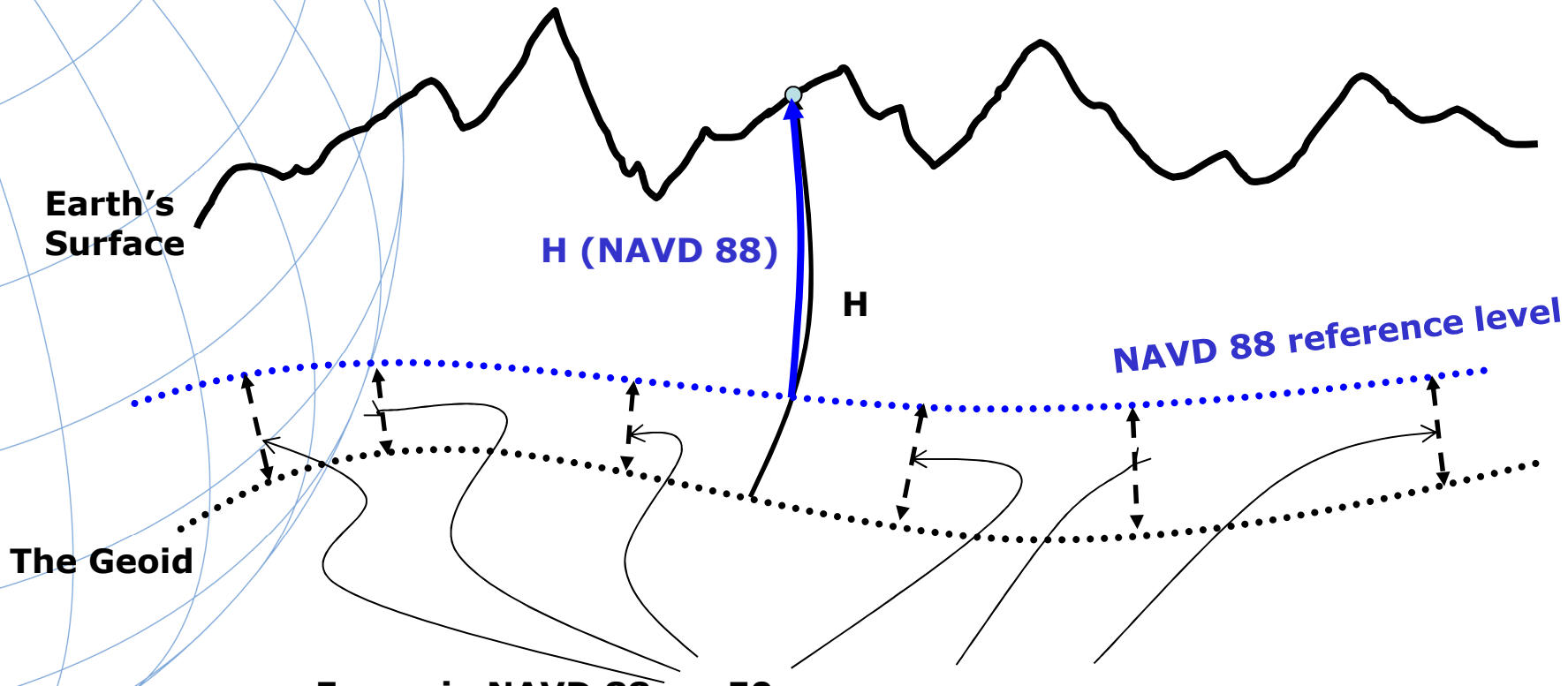
  - Convert from geopotential to <u>dynamic</u> height or <u>orthometric</u> height
  - Very time consuming and tedious

Why isn't NAVD 88 good enough anymore?

- The GPS era brought fast, accurate ellipsoid heights – naturally this drove a desire for fast, accurate orthometric heights
- Leveling the country can not be done again
  - Too costly in time and money
- Leveling yields cross-country error build-up
- Leveling requires leaving behind marks
  - Bulldozers and crustal motion do their worst
- NAVD 88 H=0 level is known not to be the geoid
  - Biases , Tilts

Orthometric Height (H)

- The distance along the *plumb line* from *the geoid* up to the point of interest



Errors in NAVD 88 : ~50 cm ave,
100 cm CONUS tilt,
1-2 meters ave in Alaska
NO tracking

Fast, Accurate *Orthometric* Heights

- GPS already gives fast accurate *ellipsoid* heights
- If the geoid were determined to highest accuracy…
- Voila… Fast, accurate orthometric heights
  - Anywhere in the nation
  - Time-changes to H determined through:
    - GPS on CORS (h changes)
    - Absolute gravity spot checks (N changes)

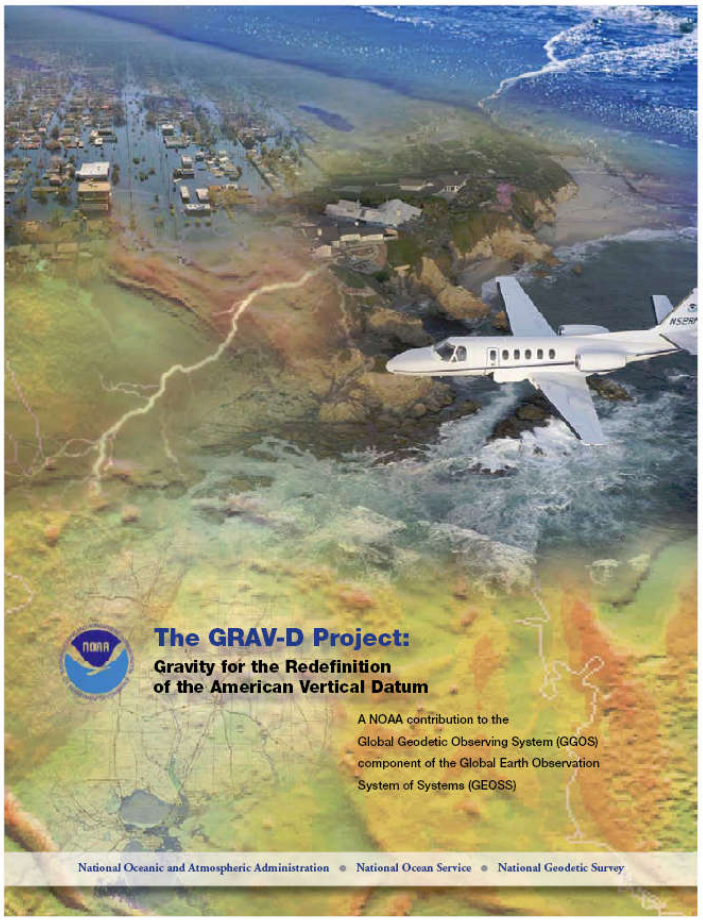
Intermission…

- To get fast, accurate, inexpensive orthometric heights, all pieces are in place except one:
  - A well known, and time-tracked geoid model
- Thus "GRAV-D"
  - Gravity for the Re-definition of the American Vertical Datum
  - Get good gravity once (airborne gravity)
  - Track gravity on a broad scale over time (absolute gravity)
  - Replace NAVD 88 with a sustainable, accurate, inexpensive vertical datum
  - Up front cost is "high", but pay off is sustainability at low-cost!

Q: What is GRAV-D?

A: A Plan (released Dec 2007)

- *Official NGS policy as of Nov 14, 2007*
  - *$38.5M over 10 years*
- *Airborne Gravity Snapshot*
- *Absolute Gravity Tracking*
- *Re-define the Vertical Datum of the USA by 2017*



Mission of NGS

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

And

- To be a world leader in geospatial activities, including the development and promotion of **standards, specifications, and guidelines**.

Mission of NOS

- To provide products, services, and information that promote safe navigation, **support coastal communities,** sustain marine ecosystems, and mitigate coastal hazards.

Mission of NOAA

- To **understand and predict changes in the Earth's environment** and conserve and manage coastal and marine resources to meet our nation's economic, social and environmental needs

Missions and GRAV-D

- NGS can neither fulfill their mission, nor contribute to the NOS and NOAA missions without modernizing the vertical datum component of the NSRS
- Only GRAV-D offers a sustainable, accurate method for doing this

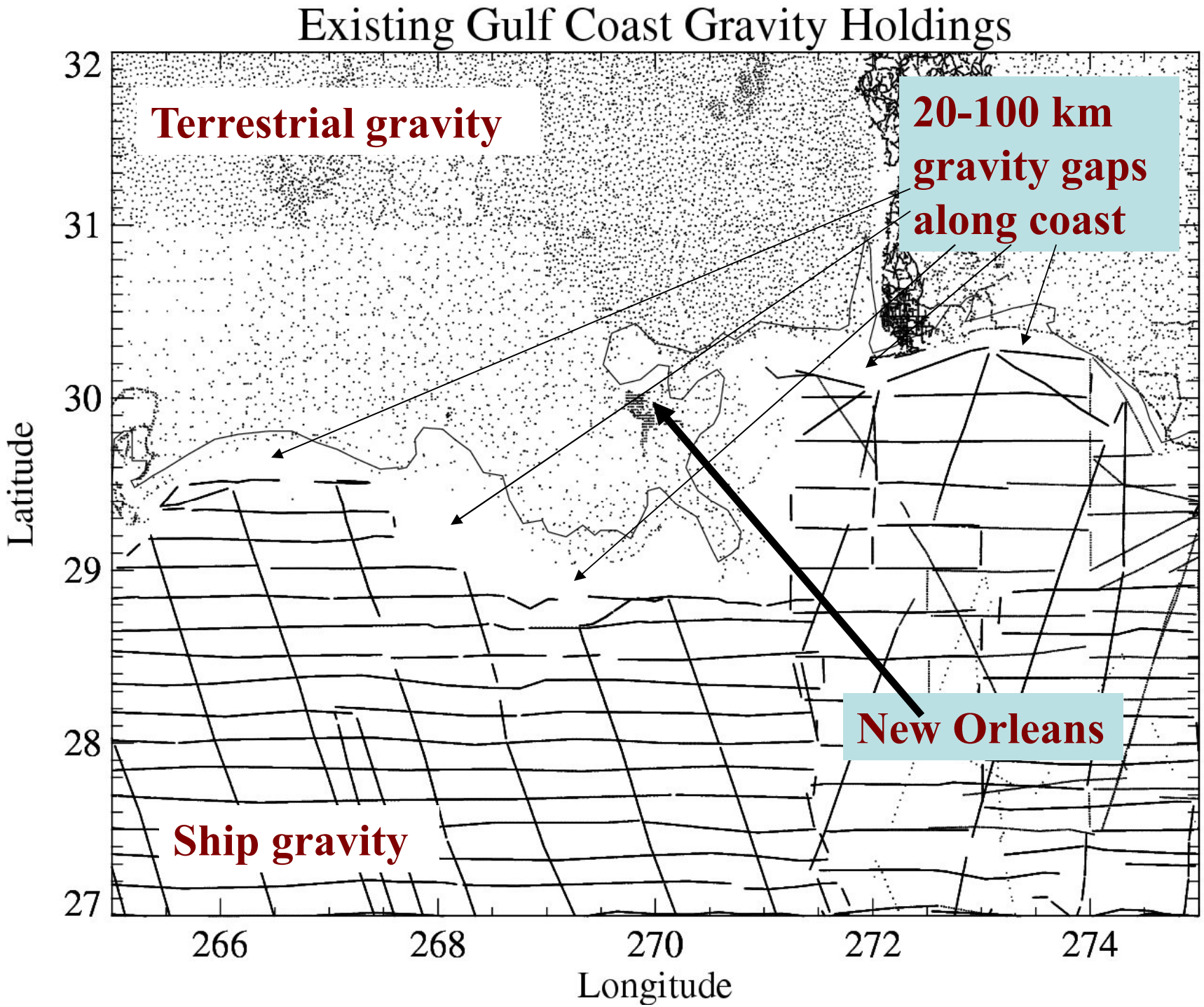
GRAV-D

- National Scale has 2 parts:
  - High Resolution Snapshot
  - Low Resolution Movie

- Local/Regional Scale has 1 part:
  - High Resolution Movie

GRAV-D

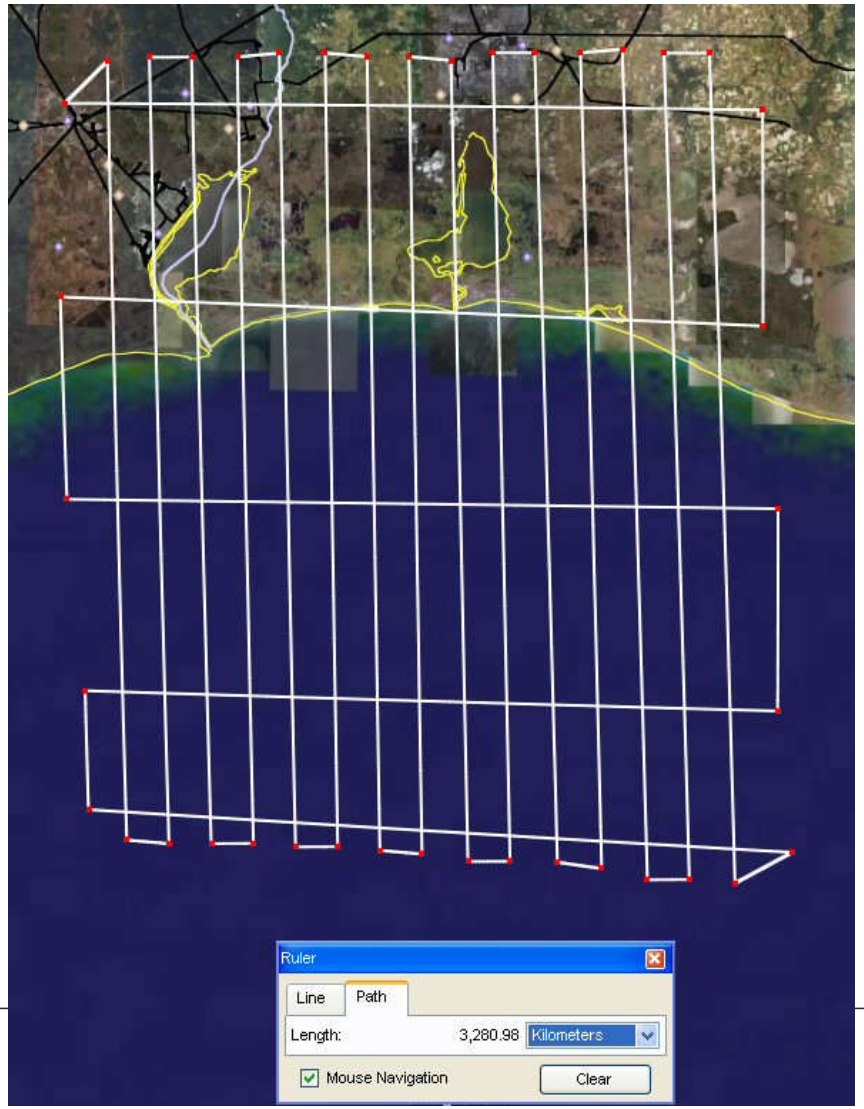
- National High Resolution Snapshot
  - Predominantly through airborne gravity
  - With Absolute Gravity for ties and checks
  - Relative Gravity for expanding local regions where airborne shows significant mismatch with existing terrestrial


Existing Gulf Coast Gravity Holdings
Terrestrial gravity
20-100 km gravity gaps along coast
New Orleans
Ship gravity
Latitude
Longitude
32
31
30
29
28
27
266
268
270
272
274

GRAV-D: Campaign I
Phase I, Part 1 - Testing

- Test varieties of flight heights / speeds / spacings for optimal ratio of

  $$: g-accuracy



GRAV-D: Campaign I
Phase I, Part 2 - Testing

- Test area for proof of concept to define vertical datum from GPS + gravimetric geoid
- PR/VI cost would run ~$300k

Daniel Winester monumentando estacion en CI-019

MAYAGUEZ A A
2008

Observaciones Gravimetricas y con GPS en el RUM 6 al 10 de nov. 2008 por Daniel Winister-Geodesta

- Gravedad Absoluta con el FG5 en CI-019
  - Por 48 horas
- GPS en Aguadilla y en estacion UPRM GPS 14
- Gravedad Relativa
  - En la estacion UPRM GPS 14
  - En el Aeropuerto Rafael Hernandez-Aguadilla
  - En estacion Mayaguez AA 2008 en CI-019

Airborne Meter

First build (Oct 2007)

Initial road tests (Nov 2007)

Unit is TAGS (Turn-key Airborne Gravity System)

- **Sensor, Software and Training sold as a package from Micro-G/LaCoste**
- **Has been flight tested and proven as the most accurate airborne meter available**

Should anyone lose sight of why NGS cares about knowing and maintaining accurate heights…

Questions/Comments?

- http://www.ngs.noaa.gov/GRAV-D/
- Prof. Linda L. Vélez-Rodríguez, MS, PE, PLS, catedrática de la Universidad de Puerto Rico Recinto Universitario de Mayagüez del programa de agrimensura del Departamento de Ingeniería Civil y Agrimensura, "Geodetic Liason" ante el "National Geodetic Survey", su correo electrónico es velezl@uprm.edu