The Global Positioning System II
Examples, Caveats
Mexico DGPS Field Campaign

- Cenotes in Tamaulipas, MX, near Aldama
Are Cenote Water Levels Related?
DGPS Static Survey of Cenote Water Levels
Determining Orthometric Heights

Ortho. Height = H.A.E. – Geoid Height

Height above MSL (Orthometric height)
Determining Orthometric Heights

Ortho. Height = (H.A.E. − Geoid Height)

Need:

1) Ellipsoid model – GRS80 – NAVD88
   - reference stations: HARN (± 2 cm), CORS (± ~2 cm)

2) Geoid model – GEOID99 (± 5 cm for US)

Procedure: Base receiver at reference station, rover at point of interest

   a) measure HAE, apply DGS corrections
   b) subtract local Geoid Height
Sources of Error

- Geoid error – model less well constrained in areas of few gravity measurements
- NAVD88 error – benchmark stability, measurement errors
- GPS errors – need precise ephemeris, tropospheric delay model, equipment (antennae should be same for base and rover)
Static Carrier-phase solutions obtained by:

- Commercial post-processing software
  - e.g. Trimble Pathfinder office
- Web-based Precise Point Position Services
  - SCOUT – Scripps, UCSB - global
  - OPUS – NGS (US and territories)
    - All services require files in RINEX format
Results

- Horizontal accuracies of $\leq 1$ cm – 1 cm
- Vertical accuracies of 2-5 cm for 4 hrs of data

Table 5. Final Results - all relative to WGS84

<table>
<thead>
<tr>
<th>Station</th>
<th>Receiver</th>
<th>Processing</th>
<th>Lat_dd</th>
<th>1_sigma_m</th>
<th>Lon_dd</th>
<th>1_sigma_m</th>
<th>HAE_m$^1$</th>
<th>1_sigma_m</th>
<th>Geoid_m$^2$</th>
<th>OH_m$^3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>CASA</td>
<td>4000SSI</td>
<td>AutoGipsy</td>
<td>22.990188256</td>
<td>0.0030</td>
<td>-98.165971883</td>
<td>0.0096</td>
<td>189.621</td>
<td>0.0213</td>
<td>-16.961</td>
<td>206.582</td>
</tr>
<tr>
<td>ZA01</td>
<td>4000SSI</td>
<td>AutoGipsy</td>
<td>22.992668149</td>
<td>0.0107</td>
<td>-98.165717957</td>
<td>0.0269</td>
<td>189.762</td>
<td>0.0463</td>
<td>-16.962</td>
<td>206.724</td>
</tr>
<tr>
<td>ZA02</td>
<td>4000SSI</td>
<td>AutoGipsy</td>
<td>22.993538927</td>
<td>0.0046</td>
<td>-98.166153000</td>
<td>0.0282</td>
<td>190.261</td>
<td>0.0341</td>
<td>-16.960</td>
<td>207.221</td>
</tr>
<tr>
<td>AL01</td>
<td>4000SSI</td>
<td>AutoGipsy</td>
<td>23.032566367</td>
<td>0.0154</td>
<td>-98.163756591</td>
<td>0.0228</td>
<td>220.069</td>
<td>0.0515</td>
<td>-16.978</td>
<td>237.047</td>
</tr>
<tr>
<td>VD01</td>
<td>4000SSI</td>
<td>AutoGipsy</td>
<td>22.992981335</td>
<td>0.0107</td>
<td>-98.161039826</td>
<td>0.0156</td>
<td>188.536</td>
<td>0.0415</td>
<td>-16.965</td>
<td>205.521</td>
</tr>
<tr>
<td>CA02</td>
<td>4000SSI</td>
<td>SCOUT</td>
<td>22.993787630</td>
<td>0.0091</td>
<td>-98.163902080</td>
<td>0.0373</td>
<td>190.506</td>
<td>0.0322</td>
<td>-16.971</td>
<td>207.477</td>
</tr>
<tr>
<td>LP01</td>
<td>4000SSI</td>
<td>SCOUT</td>
<td>22.994028670</td>
<td>0.0098</td>
<td>-98.158618590</td>
<td>0.0413</td>
<td>174.950</td>
<td>0.0321</td>
<td>-16.997</td>
<td>191.947</td>
</tr>
<tr>
<td>LPWL</td>
<td>GeoExp3</td>
<td>PO2.7</td>
<td>22.994152995</td>
<td>0.1165</td>
<td>-98.158917839</td>
<td>0.1165</td>
<td>174.760</td>
<td>0.0965</td>
<td>-16.997</td>
<td>191.757</td>
</tr>
<tr>
<td>Robin_skylight</td>
<td>GeoExp3</td>
<td>PO2.7</td>
<td>22.995796460</td>
<td>0.4680</td>
<td>-98.155486623</td>
<td>0.4680</td>
<td>185.210</td>
<td>0.4680</td>
<td>-17.013</td>
<td>202.223</td>
</tr>
</tbody>
</table>

1. HAE is the Height Above the GRS80 Ellipsoid of the Ground Reference Point.
2. "Geoid" is the height of the Geoid (relative to the NAD83 ellipsoid) at the GRP, as derived from the NGS Mexico97 geoid model. GRS80 and the NAD83 ellipsoid are virtually identical and can be used interchangeably in this instance.
3. OH is orthometric height, or more commonly mean sea level elevation. It equals [HAE] - [Geoid ht.].
GPS Applications Today

- Surveying – Tectonics, Cadastre, Geodesy
- Map Making – georeferencing, field studies
- Navigation – vehicles, missiles, robots, etc.
- Tracking – people, vehicles, pets
- “Geotagging” – apply coordinates to digital data (photos, etc.)
- Clock Synchronization (+ 10 ns)
GPS and Geologic Mapping

Two techniques:

- GPS receiver and separate, gridded paper maps
- “Mapping-grade” receiver with mapping software and interactive touch screen, e.g. Mobile devices and dedicated mapping devices
Low-Tech Mapping

- Gridded maps/photos, pencil, GPS receiver
High-Tech Mapping Tools

- Field Hardware
  - Mobile Devices
  - Outdoor tablet computers – Windows

- Field GIS/GPS Software
  - ESRI Software
    - ArcMap
    - Collector App
    - Field Maps
High-Tech Mapping Tools

Mobile GIS Apps

- Avenza Maps ($)
- iGIS
- Collector
- QGIS
- GIS Pro ($)
- FieldMove
- Field Maps

10/21/2021
High-Tech Mapping Tools

App Distinctions

- Will it accept custom georeferenced maps? (geotifs, shapefiles, PDFs)
- Will maps work offline?
- Will GPS work offline?
- Does it drop pins, geotag photos, notes etc.? E.g. Avenza Maps and many others free Apps
- Does it allow capture of lines and polygons too? E.g. iGIS, FieldMove, Collector and a few others; free to $$

10/21/2021

23
Assisted GPS (A-GPS)

Mobile Devices with GPS and WiFi or Cellular Service, e.g. LBS\(^+\)-capable phone

1. GPS Almanac provided from Server; TTFF* faster – position found by phone (Mobile Station Assisted: “MSA GPS”)

2. GPS data sent to server, position sent back (Mobile Station Based: “MSB GPS”)

* TTFF – Time to First Fix  \(^+\)LBS - location-based services
Receiver attributes

- **# of Channels**
  - One channel required for each frequency (L1, +/- L2)
  - 8 minimum (4 SVs); 12 or more desirable

- **Antenna**
  - Remote, fixed

- **Power source**
  - Internal, external

- **Data Storage**
  - Way-points vs. data logging
  - Positions vs. raw data

- **Data upload & download**
  - Data dictionary upload for storing positions by attributes (pt., line, area)
Receiver attributes

- DGPS capable
  - Beacon antenna for real-time DGPS
  - Download and post-process

- WAAS capable

- Ionosphere Correction or model
  - Dual channel vs. single channel receiver

- Troposphere model?
Recent Developments

- Hand-held equipment – Field GIS
- WAAS, LAAS
- Other Global Navigation Satellite Systems (GNSS)
  - European Union *Galileo* System (2014) and EGNOS SBAS
  - Russia - *GLONASS* (23 SVs) + SBAS services
  - Chinese *BeiDou* Navigational System (*BDS*); 14 SVs, 35 by 2020; +SBAS services)
- Regional Satellite Systems
  - Gagan – India (2012)
  - Japan –MSAS (QZSS?)
SBAS Service Areas

SBAS = Satellite Based Augmentation Systems