Introduction into Global Positioning Systems (GPS)

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Overview

• How Does GPS Work
• Sources of Error
• Correction Types/Services
• Accuracy vs. Repeatability
• Purchase Considerations
• Introduction into GIS
How Does GPS Work

- **3 Segments**
  - Space
  - Control
  - User

- **Space Segment**
  - 24 of 34 satellites utilized in 6 planes
  - Signal broadcast on two frequency signals, L1 and L2
  - L5 frequency is undergoing testing since April 2009

- **Control Segment**
  - 5 monitoring and controlling stations worldwide
  - Track satellites and provide clock and path corrections
How Does GPS Work

• **User Segment**
  – GPS unit calculates distance from satellites to rover
    • Signal received on the L1 and L2 frequency
  – Minimum satellites for position calculation
    • 4 satellites – 3D
    • 3 satellites – 2D

• **Future of GPS**
  – Civilian access to L5 signal
    • Increased precision
    • Increased availability
Sources of Error

- Receiver Noise (0.3 m)
- Satellite Clock Drift (1.5 m)
- Orbit Estimation Error (2.5 m)
- Atmospheric Delay (5.5 m)
- Multipath (0.6 m)
Types of Correction

• Post processing

• Real-time
  – Correction data received immediately at the mobile GPS receiver
  – Differential GPS (DGPS)
    • Compares signal received to true base station position
    • Position difference is broadcast out via a DGPS Radiobeacon Antenna or by geostationary satellites
Sources of Real-Time Correction

• Satellite-based differential correction (wide-area)
  – WAAS
  – OmniStar
  – John Deere Starfire

• Local Area differential correction
  – US Coast Guard beacon
  – RTK
  – CORS
Correction Services

- **Wide Area Augmentation System (WAAS)**
  - Corrects for GPS signal errors caused by
    - Atmospheric disturbances
    - Clock error
    - Satellite orbit
  - Compatible with basic GPS signal structure
    - Standard on most GPS receivers
    - Purchase of additional equipment is not necessary
  - 3 to 5 meter (free)

Image courtesy of Garmin
Correction Services

• OmniStar
  – Subscription service
  – Receiver must be compatible
    • All Omnistar receivers
    • Trimble AgGPS and ProXRS
    • Certain DGPS receivers from AgLeader, Case IH, and Hemisphere
  – Service Type
    • VBS – sub-meter ($800 / year)
    • XP – 20 cm ($800 / year)
    • HP – 10 cm ($1500 / year)
Correction Services

- **John Deere Starfire System**
  - SF1 – Single frequency
    - 1 meter (free)
  - SF2 – Dual frequency
    - 10 cm ($800 / year)
  - WAAS and RTK
    - RTK – 3 cm (no subscription necessary)

- **US Coast Guard Beacon**
  - Radio beacon positioned around navigable waterways
    - Must be within 300 miles of beacon
    - Signal fades between 125 to 300 miles
  - 2 meters (free)
Correction Services

- **Real-Time Kinematics (RTK)**
  - Utilizes base station to transmit correction
    - 6 mile limitation (line of sight)
      - Repeaters can extend distance
  - Base station creation
    - Setup over a known survey point
    - If survey point unavailable
      - Archive data for post-processing (OPUS)
      - Setup at highest location, or
      - If all fields near house, set base station on rooftop
  - Most accurate system available (1-3 cm)
Correction Services

- Continuously Operating Reference Station (CORS)
  - Similar to RTK system
  - Hundreds of sites nationwide
  - Eliminates need for a personal base station
  - Rover generally communications via cellular phone
  - 4 cm accuracy when within 30 mi of station
    - Accuracy degrades after 30 miles
Precision (Repeatability) and Accuracy

- High Accuracy and High Precision
- Low Accuracy and High Precision
- Low Accuracy and Low Precision
Accuracy vs. Repeatability

- GPS Drift
  - Accuracy measured on a pass-to-pass basis
  - Pass-to-pass
    - < 15 minutes
GPS Applications

- **Low-Cost**
  - Recreation
  - Scouting
  - Navigation

- **Sub-Meter**
  - Yield Monitoring
  - Soil Sampling

- **Sub-Foot**
  - Boundary Mapping

- **RTK**
  - Surveying
  - Auto Steer
  - Planting
  - Strip-Tillage
  - Controlled Traffic

Images courtesy of Garmin, Topcon, and GPS-Ag.com.au
Purchase Considerations

• Accuracy
• DGPS
  – WAAS or Coast Guard Enabled
  – Purchase Correction Service
• Interfacing
  – Cables
  – Connectors (DB9)
  – Output (NMEA)
• Cost
  – $80 – Basic Receiver (Sub 3-m)
  – $45,000 – Survey Grade Systems (cm)

Images courtesy of John Deere and Trimble
Introduction into GIS

- Geographic Information System (GIS)
  - Textbook Definition (www.gis.com)
    - (GIS) integrates hardware, software, and data for capturing, managing, analyzing, and displaying all forms of geographically referenced information.

Images courtesy of Garmin, UW-Extension, and Western Land Specialists.
GIS Software Packages

Garmin Mapsource (free)

Google Earth (free)

ArcMap ($1500*)

Mapshots EASi Suite ($995)

Ag Leader SMS ($995)
Degrees vs. Decimal Degrees

Degrees, Minutes, Seconds

- Converting Degrees, Minutes, Seconds to Decimal Degrees
  - Formula
    - Degrees + Minutes/60 + Seconds/3600
  - Website

Decimal Degrees
Summary

- GPS is a global satellite navigation system
  - 3 segments: space, control, and user
  - 4 satellites required to calculate 3D position
- Multiple correction services for GPS errors
  - WAAS, OmniStar, JD Starfire, USCG Beacon, RTK and CORS
  - Varying cost and accuracy associated with each correction service
- Accuracy and repeatability differ
- Must determine application before purchasing GPS equipment
- GIS is the integration of hardware, software, and data allowing for analysis, management, and mapping