*AGRO/MSYM/AGEN 431*

# GPS and Geographic Coordinates

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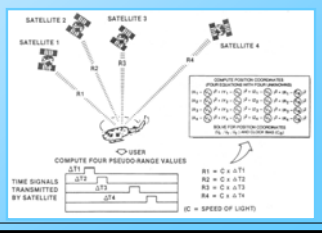
## Global Navigation Satellite System

- **The Global Navigation Satellite System (GNSS) is a generic term for a space-based radio-navigation system that provides the capability to determine geographic location anywhere on Earth**
- **Primary tool for real-time determination of field locations**




## Current GNSS


- Launched: 1978
- 24 Satellite Constellation


- Launched: 1982
- Current Satellite Constellation: 17
- Planned Constellation: 24

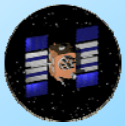


- Test Satellite Launched: Dec. 2005
- Planned Constellation: 30 Satellites

*Provided by Michael Gomes, TSD Integrated Controls*

## GPS - NAVSTAR

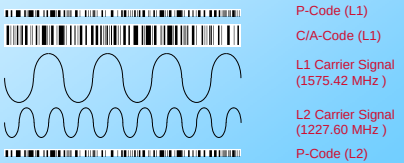
**G**lobal **P**ositioning **S**ystem
**NAV**igation **S**ystem for **T**iming **A**nd **R**anging



- US DoD positioning system
- Full constellation - 24 satellites
- Currently operational - 27 satellites
- Orbital planes - 6
- Inclination - 55°
- Altitude - 20,180 km (10,900 nautical miles)
- Orbital period - 11 h 58 min
- Coordinate system – WGS-84

## GPS Signal Structure

**Two carrier frequencies:**
**- The L1 and L2**
**Three code messages:**
**- C/A-Code (L1 only) & P-Code (L1 & L2)**
**Informational Messages**
**- Ephemeris - Almanac**



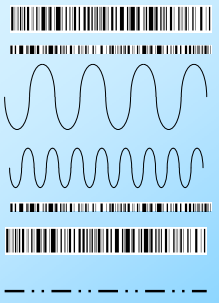

*Provided by Michael Gomes, TSD Integrated Controls*

## GLONASS

**GLO**bal **NA**vigation **S**atellite **S**ystem
**GLO**bal'naia **NA**vigatsionnaia **S**putnikovaia **S**istema

- Russian Military Positioning System
- Full constellation - 24 satellites
- Currently operational - 17 satellites
- Orbital planes - 3
- Inclination – 64.8°
- Altitude - 19,130 km
- Orbital period - 11 h 15 min 40 s
- Coordinate System – PZ-90

## GLONASS Signal Structure



C1 Modulated Code

C2 Modulated Code

Carrier Signal 1
1602MHz+n 9/16Mhz

Carrier Signal 2
1246MHz+n 7/16Mhz

C2 Modulated Code

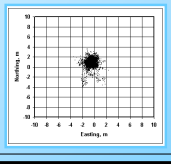
C1 Modulated Code
*(*New M-Class Sats Only)*

Informational Messages
(Health, Almanac, Ephemeris)

*Provided by Michael Gomes, TSD Integrated Controls*

## Sources of Error

- Atmospheric error
  - Imposed by ionosphere (accountable)
  - Imposed by troposphere (non-accountable)
- Clock error
  - Error of 0.000001 s means 1000 ft
- Multipath error
- Delusion of Precision (DoP)
- Selective availability

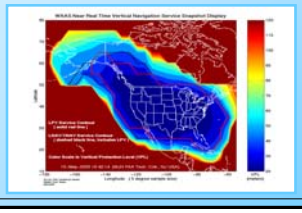


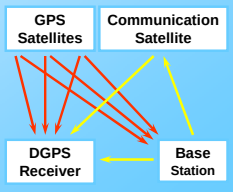
### Solutions:

- Carrier-Phase position
- GPS Almanac
- Mask angle
- Post-processing
- Differential correction

## Differential Correction

- Software data filtering
- Beacon (Coast Guard)
- Private Satellite Service (Omnistar, StarFire)
- WAAS (Wide Area Augmentation System)
- Portative Station (RTK)






## GPS Receiver Performance

| | Low | Middle | High | RTK |
|---|---|---|---|---|
| Price | $200 to $800 | $800 to $1,500 | $1,500 to $10,000 | $40,000 to $50,000 |
| Differential Source | WAAS | WAAS Beacon | WAAS Beacon Subscription, Dual Frequency | Need Base Station |
| Static Accuracy | 5 to 12 Feet | 3 to 9 Feet | < 3 Foot | 1 Inch |
| Static GPS Position Location | Not Stable | Somewhat Stable | Stable | Stable |
| Advantages | Compact in Size Mobile Smart Antenna | Same as Low | Can be used for most agricultural operations. | Highly Accurate, Survey Grade |
| Uses | Scouting (> 15 ft. area) Line Mapping | Mapping Guidance | Mapping Guidance | Elevation and Drainage Mapping Guidance |

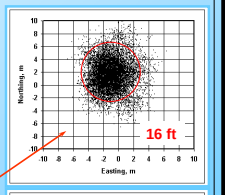
THE OHIO STATE UNIVERSITY EXTENSION

## Stationary Comparison

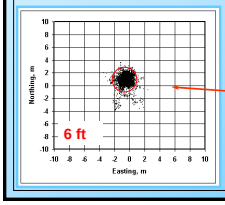
**Roof of Biological Systems Engineering Laboratory:**

- Latitude 40° 49' 57.45367"
- Longitude: 96° 40' 10.35077"
- Altitude: 362.766 m

**Recording every minute for 7 days**

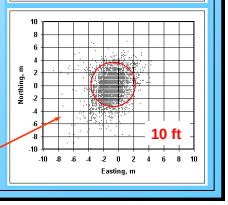



Novatel Receiver – No DGPS

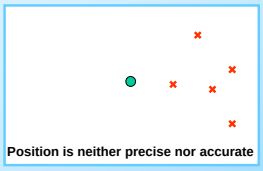


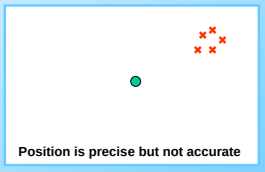

Outback Receiver – WAAS Enable

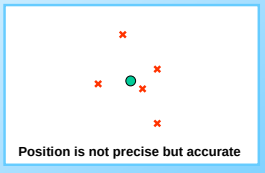
eTrex Receiver – WAAS Enable

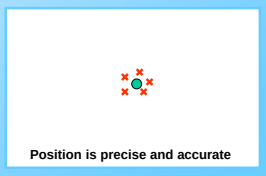



## Precision versus Accuracy


Position is neither precise nor accurate

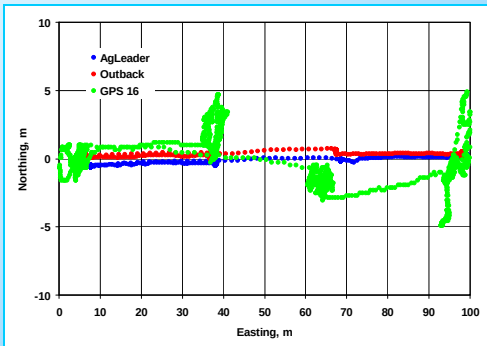

Position is precise but not accurate


Position is not precise but accurate

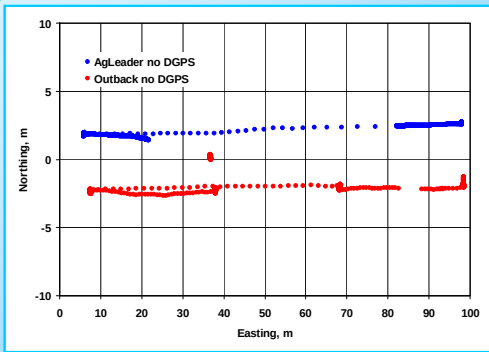

Position is precise and accurate

## Dynamic Comparison

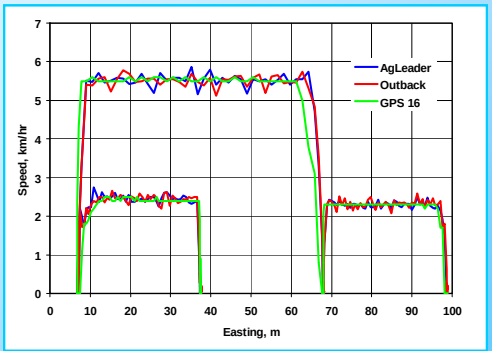

## GPS Comparison (Position)



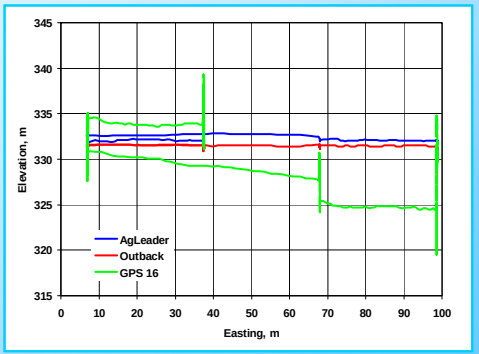

## GPS Comparison (Position)



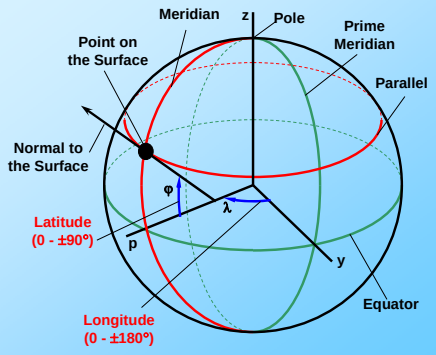

## GPS Comparison (Speed)




## GPS Comparison (Elevation)



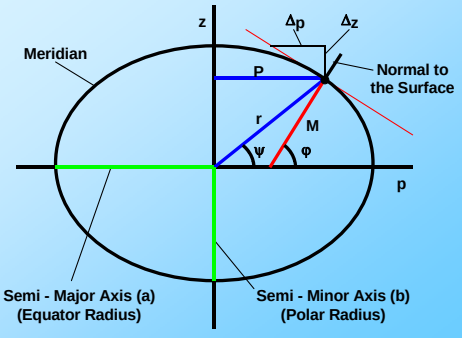

## Geographic Location



## Geometrical Model of the Earth

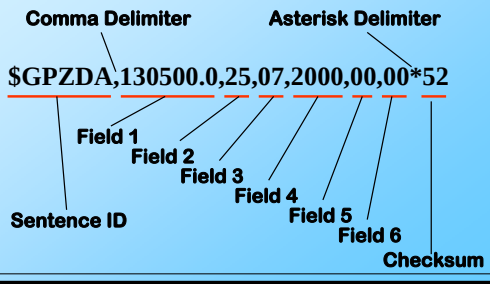
- The Earth is <u>almost</u> a perfect sphere (Radius = 6,370,997 m)
- However, ellipticity of Earth is approximately 0.003353 > 0
- There are several ellipsoid models
- GPS uses WGS 84 model
  - Equatorial Radius (Semi-Major Axis) <u>a = 6,378,137 m</u>
  - Polar Radius (Semi-Minor Axis) <u>b = 6,356,752.3142 m</u> *(defined as 1/f = 1/298.257223563, where f = (a-b)/a)*

## WGS 84 Ellipsoid




## NMEA-0183 Output

*National Marine Electronics Association (NMEA) Simple ASCI serial communication (Baud Rate: 4800, Data Bits: 8, Parity: None, Stop Bits: 1)*




## Some NMEA-0183 Sentences

| Sentence ID | What is included |
|---|---|
| GGA | Global positioning system fix data |
| GLL | Geographical position (latitude and longitude) |
| GSA | GPS DOP and active satellites |
| GSV | GPS satellites in view |
| RMC | Recommended minimum specific GPS data |
| VTG | Track made good and ground speed |
| ZDA | UTC time & date and local time zone |

## Listening to a GPS Receiver

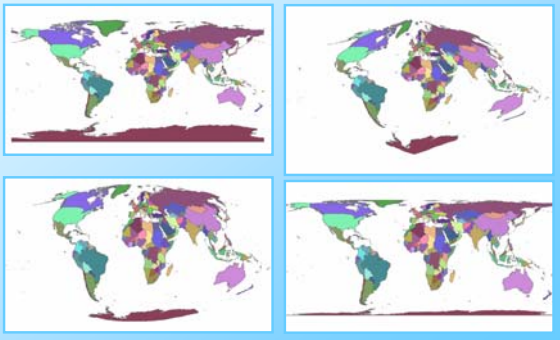
```
$GPGGA,205611.00,4049.93479,N,09640.21983,W,2,07,1.0,359.2,M,-28.5,
M,5.0,0122*7C

$GPGLL,4049.93479,N,09640.21983,W,205611.00,A*14

$GPVTG,264.71,T,264.71,M,1.59,N,2.95,K*4D

$GPZDA,205611.00,31,1,2003,,*55

$GPRMC,205611.00,A,4049.93479,N,09640.21983,W,1.6,264.7,310103,,*23

$GPGSV,3,1,09,04,81,054,54,05,40,307,54,07,46,077,54,09,28,255,51*7A

$GPGSV,3,2,09,10,03,180,,20,10,036,45,24,62,224,57,28,09,142,48*71

$GPGSV,3,3,09,30,04,316,42,,,,,,,,,,,,*45

$GPGSA,M,3,04,05,07,09,20,24,28,,,,,,1.7,1.0,1.3*3A
```

*HyperTerminal Output*

## Spatial Data Display

- Datum (global coordinate system)
  - North American Datum NAD 27
  - North American Datum NAD 83
  - World Geodetic System WGS 84 (GPS data)
- Projection (map display)
  - Universal Transverse Mercator (UTM)
  - State Plane
  - Local coordinates
  - Not projected (Latitude and Longitude)

## Map Projection



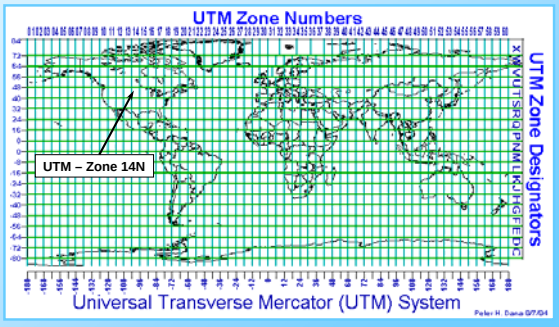
## Projection Comparison


*http://maps.unomaha.edu/Peterson/gis/notes/MapProjCoord.html*

## State Plane Coordinate System (SPCS)

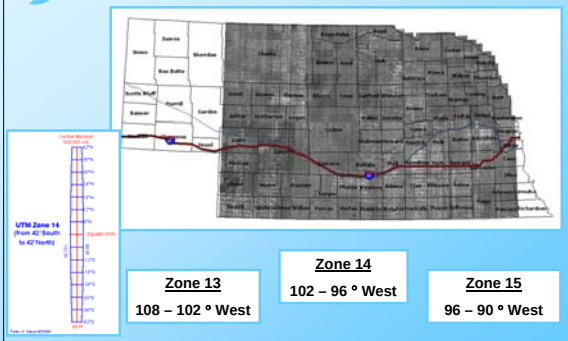
- **A standard set of projections for the United States based on either the Lambert Conformal Conic or Transverse Mercator projection, depending on the orientation of each state. Large states commonly require several state plane zones.**
- **SPCS 83 Federal Information Processing Standard (FIPS) zone 2600**
  - **SPCS 27 FIPS zones 2601**
  - **SPCS 27 FIPS zones 2602**

## The Universal Transverse Mercator (UTM) Projection




*http://www.colorado.edu/geography/gcraft/notes/mapproj/mapproj_f.html*

## UTM in Nebraska




*http://www.colorado.edu/geography/gcraft/notes/mapproj/mapproj_f.html* *http://ortho.gisworkshop.com*

## GPS Lat/Lon Processing

- **Convert GPS latitude longitude into decimal degrees**
- **Make longitude negative**
- **Compute conversion factors for a specific latitude**
- **Plot and analyze the data**

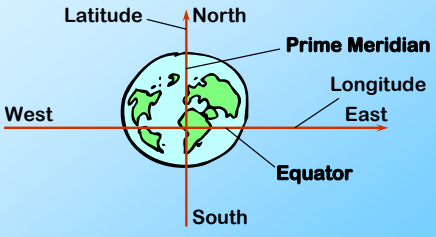
## Decimal Degrees

**Degrees = Degrees +Minutes/60 + Seconds/3600**

**NMEA-0183 Output for Latitude is ddmm.mmmm**

**In Decimal Degrees this will be:**
**dd.dddddd = dd + mm.mmmm/60**

## Global Coordinate System




**South latitude and west longitude are negative**

## Longitude and Latitude Conversion

$$F_{lon} = \frac{\pi}{180^\circ}\left(\frac{a^2}{\sqrt{a^2\cos^2\varphi + b^2\sin^2\varphi}} + h\right)\cos\varphi$$

$$F_{lat} = \frac{\pi}{180^\circ}\left(\frac{a^2 b^2}{\left(a^2\cos^2\varphi + b^2\sin^2\varphi\right)^{\frac{3}{2}}} + h\right)$$

*University of Nebraska Tractor Testing Lab*
*Latitude (φ): 40° 49.9576'*
*Longitude (λ): 96° 40.1725'*
*Elevation (h): 362 m*

**$F_{lon}$ = 84353 m = 276749 ft**
**$F_{lat}$ = 111057 m = 364360 ft**

## Longitude/Latitude Conversion

| Latitude, deg | Flon, m/deg | Flat, m/deg | Latitude, deg | Flon, m/deg | Flat, m/deg | Latitude, deg | Flon, m/deg | Flat, m/deg |
|---|---|---|---|---|---|---|---|---|
| 0 | 111319 | 110574 | 31 | 95504 | 110869 | 62 | 52398 | 111446 |
| 1 | 111303 | 110575 | 32 | 94493 | 110887 | 63 | 50673 | 111462 |
| 2 | 111252 | 110576 | 33 | 93453 | 110904 | 64 | 48932 | 111477 |
| 3 | 111168 | 110577 | 34 | 92385 | 110922 | 65 | 47176 | 111493 |
| 4 | 111050 | 110580 | 35 | 91288 | 110941 | 66 | 45405 | 111507 |
| 5 | 110899 | 110583 | 36 | 90164 | 110959 | 67 | 43620 | 111522 |
| 6 | 110714 | 110586 | 37 | 89012 | 110978 | 68 | 41822 | 111536 |
| 7 | 110495 | 110591 | 38 | 87832 | 110996 | 69 | 40010 | 111549 |
| 8 | 110243 | 110596 | 39 | 86626 | 111015 | 70 | 38187 | 111562 |
| 9 | 109958 | 110601 | 40 | 85394 | 111035 | 71 | 36351 | 111574 |
| 10 | 109639 | 110608 | 41 | 84135 | 111054 | 72 | 34504 | 111586 |
| 11 | 109288 | 110615 | 42 | 82851 | 111073 | 73 | 32647 | 111598 |
| 12 | 108903 | 110622 | 43 | 81541 | 111093 | 74 | 30779 | 111608 |
| 13 | 108485 | 110630 | 44 | 80206 | 111112 | 75 | 28902 | 111618 |
| 14 | 108034 | 110639 | 45 | 78847 | 111132 | 76 | 27016 | 111628 |
| 15 | 107550 | 110649 | 46 | 77463 | 111151 | 77 | 25121 | 111637 |
| 16 | 107034 | 110659 | 47 | 76056 | 111171 | 78 | 23219 | 111645 |
| 17 | 106486 | 110669 | 48 | 74625 | 111190 | 79 | 21310 | 111653 |
| 18 | 105905 | 110680 | 49 | 73172 | 111210 | 80 | 19393 | 111660 |
| 19 | 105292 | 110692 | 50 | 71696 | 111229 | 81 | 17471 | 111666 |
| 20 | 104647 | 110704 | 51 | 70198 | 111248 | 82 | 15544 | 111672 |
| 21 | 103970 | 110717 | 52 | 68678 | 111267 | 83 | 13611 | 111677 |
| 22 | 103262 | 110730 | 53 | 67137 | 111286 | 84 | 11675 | 111682 |
| 23 | 102523 | 110744 | 54 | 65576 | 111305 | 85 | 9735 | 111685 |
| 24 | 101752 | 110758 | 55 | 63994 | 111324 | 86 | 7791 | 111688 |
| 25 | 100950 | 110773 | 56 | 62393 | 111342 | 87 | 5846 | 111691 |
| 26 | 100118 | 110788 | 57 | 60772 | 111360 | 88 | 3898 | 111693 |
| 27 | 99255 | 110804 | 58 | 59133 | 111378 | 89 | 1949 | 111694 |
| 28 | 98362 | 110819 | 59 | 57475 | 111395 | 90 | 0 | 111694 |
| 29 | 97439 | 110836 | 60 | 55800 | 111412 | | | |
| 30 | 96486 | 110852 | 61 | 54107 | 111429 | | | |

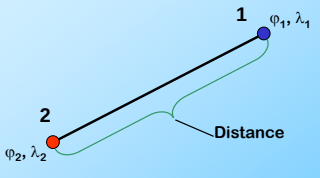
**1 ft = 0.3048 m**

## How long is 0.000001 deg ?

*Assume:* *Latitude = 40.83°*
*Longitude = 86.67°*
*a = 6378137 m*
*b = 6,356,752.3142 m*
*h = 362 m*

***Answer: Latitude: 0.1111 m = 4.37 in***
***Longitude: 0.0844 m = 3.32 in***

## Distance between two points




$$Distance = \sqrt{\left(F_{Lat}(\varphi_1 - \varphi_2)\right)^2 + \left(F_{Lon}(\lambda_1 - \lambda_2)\right)^2}$$

## What is the distance?

$GPGLL,4027.026627,N,08704.962922,W,180520.00,A,D*79

$GPGLL,4027.026173,N,08704.994100,W,180534.00,A,D*7B

h = 170 m

***Answer: Distance = 44.1 m = 145 ft***

## What is the average speed?

$GPGLL,4027.026627,N,08704.962922,W,180520.00,A,D*79

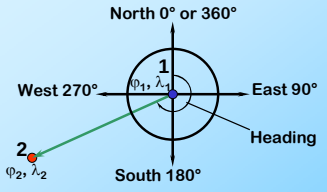
$GPGLL,4027.026173,N,08704.994100,W,180534.00,A,D*7B

h = 170 m

**Time = 14 s**

***Answer: Average Speed = 3.15 m/s = 11.3 km/hr = 7.04 mi/hr***

## Travel direction (heading)




$$\begin{cases} if \quad \lambda_1 = \lambda_2 \quad then \quad \begin{cases} if \quad \varphi_1 < \varphi_2 \quad then \quad Heading = 0° = 360° \\ if \quad \varphi_1 > \varphi_2 \quad then \quad Heading = 180° \end{cases} \\ if \quad \lambda_1 < \lambda_2 \quad then \quad Heading = 90° - \arctan\left(\frac{F_{Lat}(\varphi_2 - \varphi_1)}{F_{Lon}(\lambda_2 - \lambda_1)}\right) \\ if \quad \lambda_1 > \lambda_2 \quad then \quad Heading = 270° - \arctan\left(\frac{F_{Lat}(\varphi_2 - \varphi_1)}{F_{Lon}(\lambda_2 - \lambda_1)}\right) \end{cases}$$

## What is the direction of travel?

$GPGLL,4027.026627,N,08704.962922,W,180520.00,A,D*79

$GPGLL,4027.026173,N,08704.994100,W,180534.00,A,D*7B

h = 170 m

***Answer: Heading = 269° (West)***

## Perimeter and Area

$$X = (Longitude - Min(Longitude)) \cdot F_{Lon}$$
$$Y = (Latitude - Min(Latitude)) \cdot F_{Lat}$$

$$Perimeter = \sum_{i=1}^{n} \sqrt{(X_i - X_{i+1})^2 + (Y_i - Y_{i+1})^2}$$

$$Area = \frac{1}{2}\left|\sum_{i=1}^{n}(X_i \cdot Y_{i+1} - X_{i+1} \cdot Y_i)\right|$$

***http://bse.unl.edu/adamchuk***
***E:mail: vadamchuk2@.unl.edu***