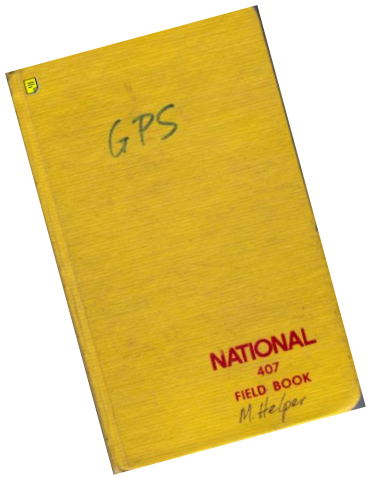
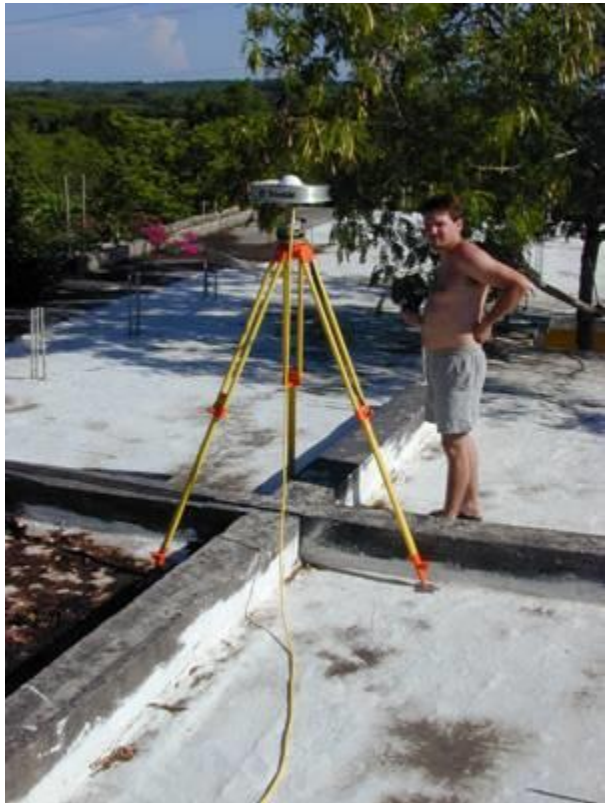
The Global Positioning System II
Examples, Caveats

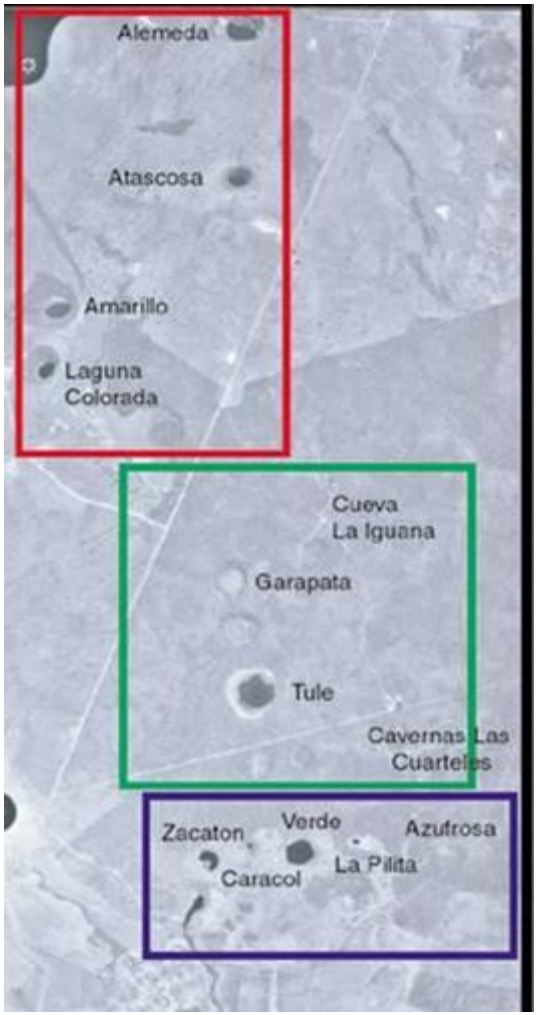




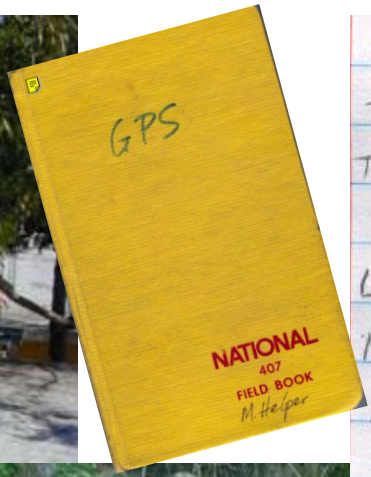
Mexico DGPS Field Campaign

- Cenotes in Tamaulipas, MX, near Aldama

Are Cenote Water Levels Related?



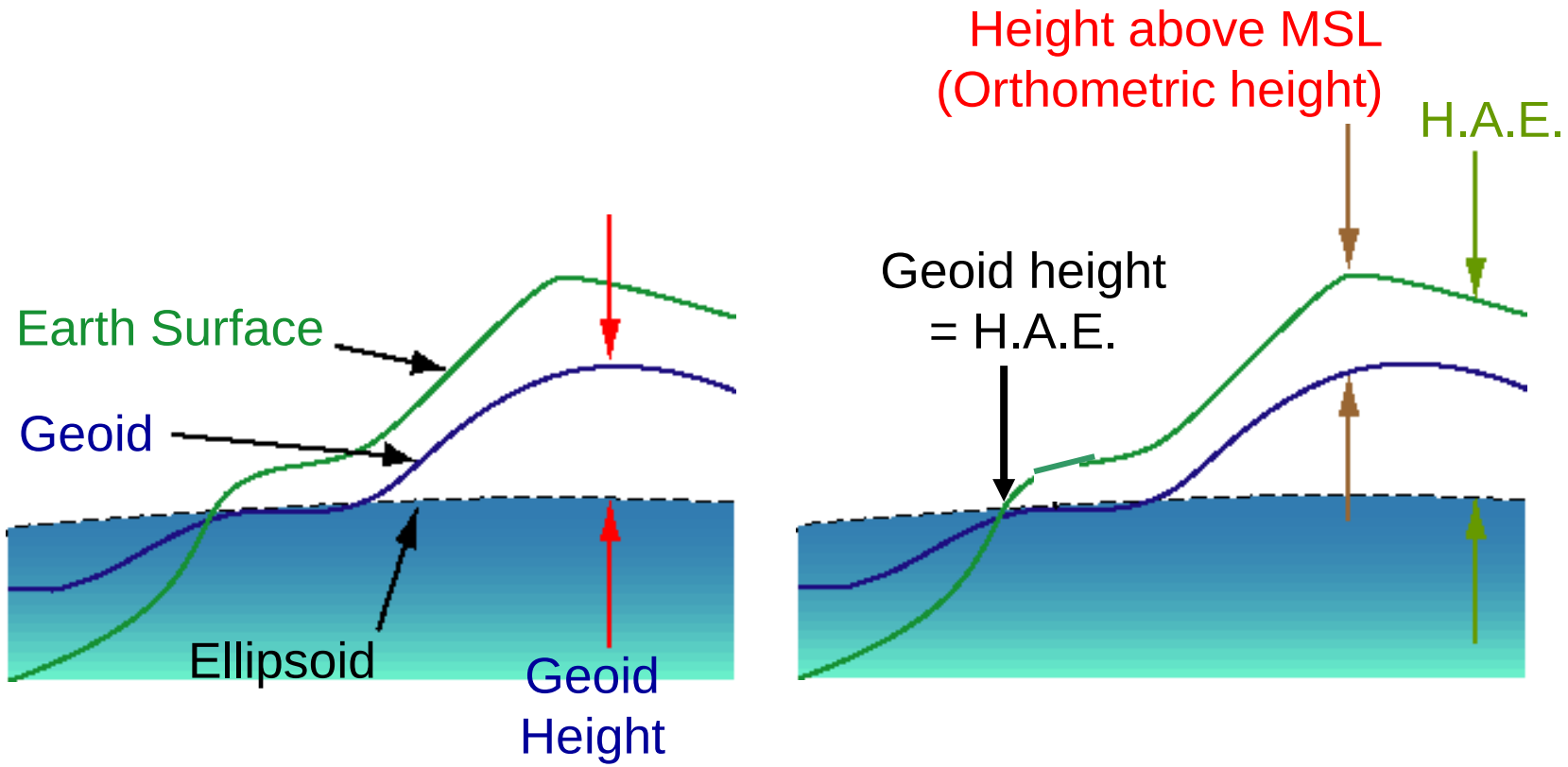
DGPS Static Survey of Cenote Water Levels



GPS equip.
Trimble 4000 SSI receivers (2)
TRM29659 antennae (2)
Heavy duty antennae cable (2)
Lt. wt antennae cable (1)
12-v carbatteries (3)
battery charger (1)
battery - receiver cables (2)
wooden tripods (2)
tribrachs (2)
ht stick (1)
Data transfer cables
Laptop w/ P.O. v.2.7
Copy of P.O. v.2.7

Determining Orthometric Heights

- Ortho. Height = H.A.E. – Geoid 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 ephemeri, 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 ≤1 cm – 1 cm
- Vertical accuracies of 2-5 cm for 4 hrs of data

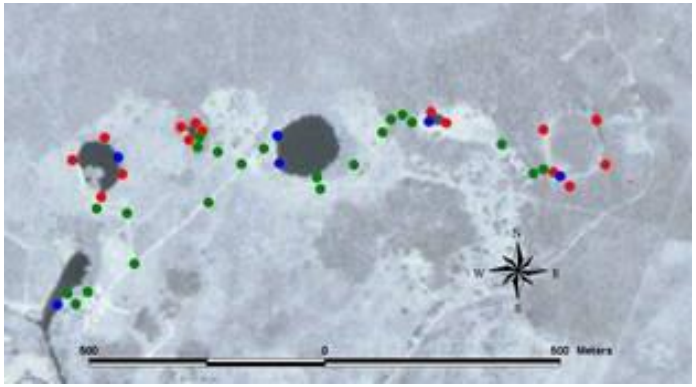


Table 5. Final Results - all relative to WGS84

Station	Receiver	Processng	Lat_dd	1_sigma_m	Lon_dd	1_sigma_m	HAE_m[1]	1_sigma_m	Geoid_m[2]	OH_m[3]
CASA	4000SSI	AutoGipsy	22.990188255	0.0030	-98.165971883	0.0096	189.621	0.0213	-16.961	206.582
ZA01	4000SSI	AutoGipsy	22.992668149	0.0107	-98.165717957	0.0269	189.762	0.0463	-16.962	206.724
ZA02	4000SSI	AutoGipsy	22.993538927	0.0046	-98.166153000	0.0282	190.261	0.0341	-16.960	207.221
AL01	4000SSI	AutoGipsy	23.032566367	0.0154	-98.163756591	0.0228	220.069	0.0515	-16.978	237.047
VD01	4000SSI	AutoGipsy	22.992981335	0.0107	-98.161039826	0.0156	188.536	0.0415	-16.985	205.521
CA02	4000SSI	SCOUT	22.993787630	0.0091	-98.163902080	0.0373	190.506	0.0322	-16.971	207.477
LP01	4000SSI	SCOUT	22.994028670	0.0098	-98.158618590	0.0413	174.950	0.0321	-16.997	191.947
LPWL	GeoExp3	PO2.7	22.994152995	0.1165	-98.158917839	0.1165	174.760	0.0965	-16.997	191.757
Robin_skylight	GeoExp3	PO2.7	22.995796460	0.4680	-98.155486623	0.4680	185.210	0.4680	-17.013	202.223

[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 interchangable 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)

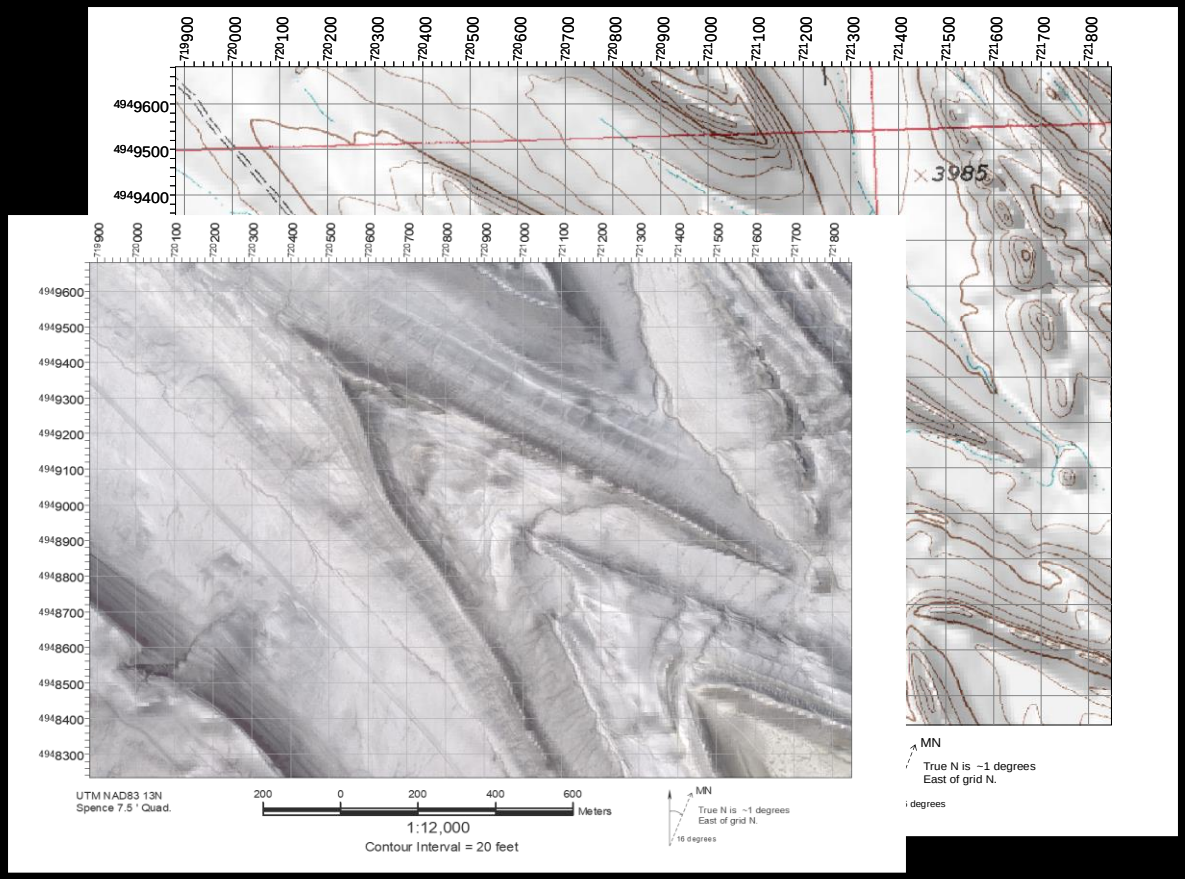
GPS and Geologic Mapping

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



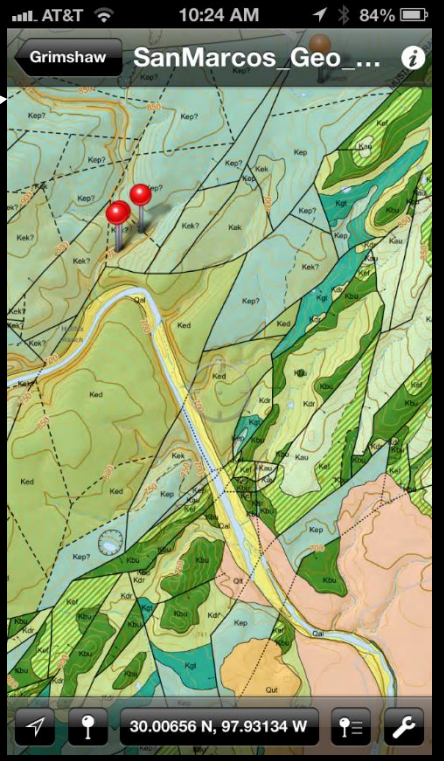
High-Tech Mapping Tools

- 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



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 $$

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)

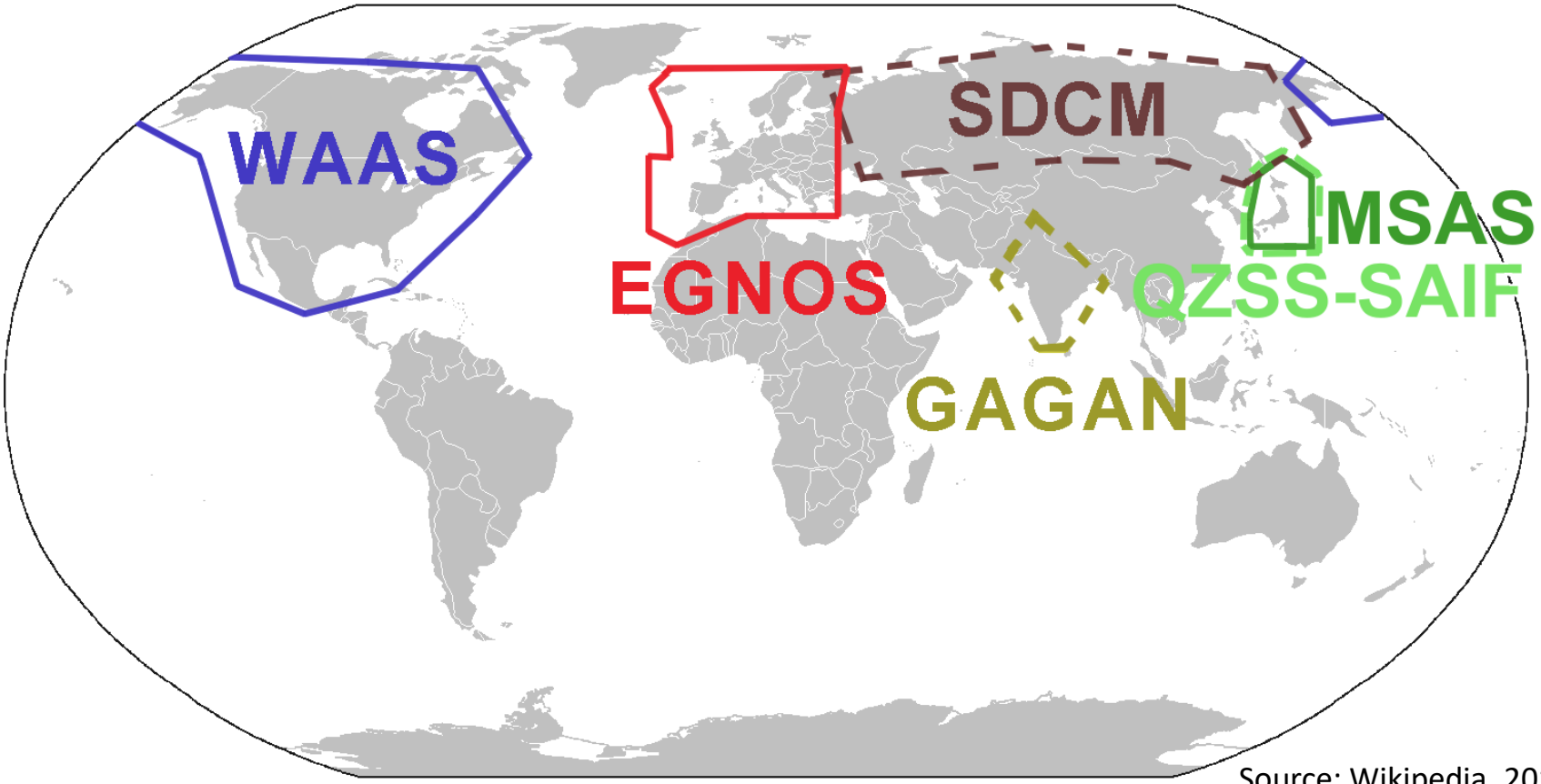
Receiver attributes

- 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



Source: Wikipedia, 2015

SBAS = Satellite Based Augmentation Systems