GNSS 101

Resource GPS Spring Meeting

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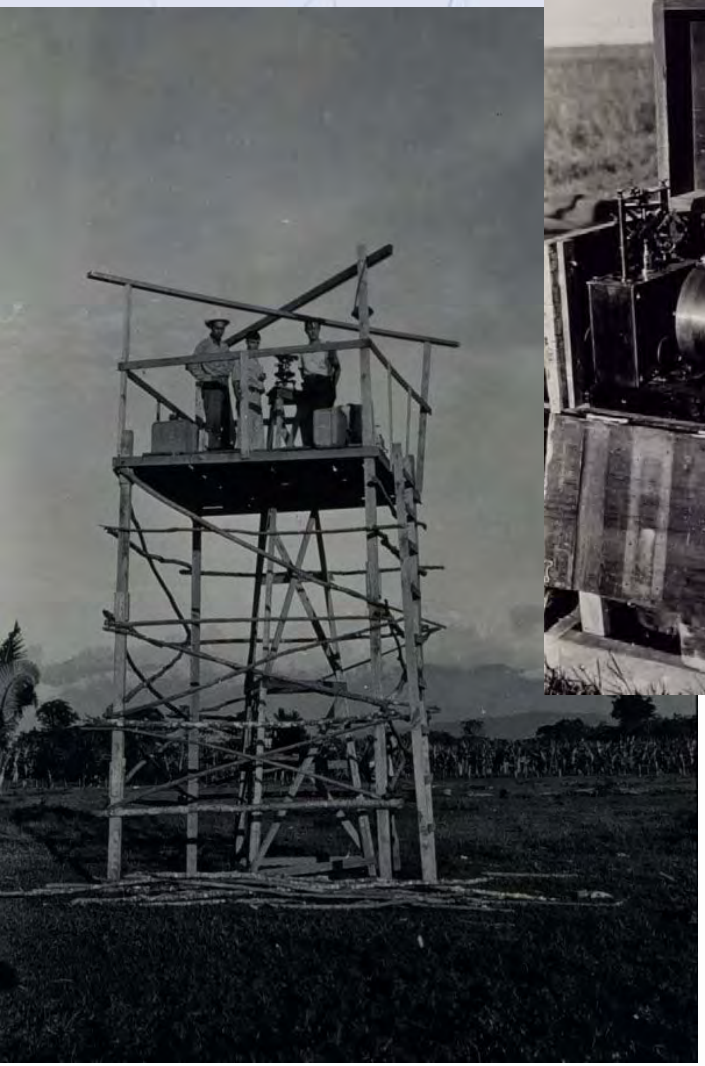
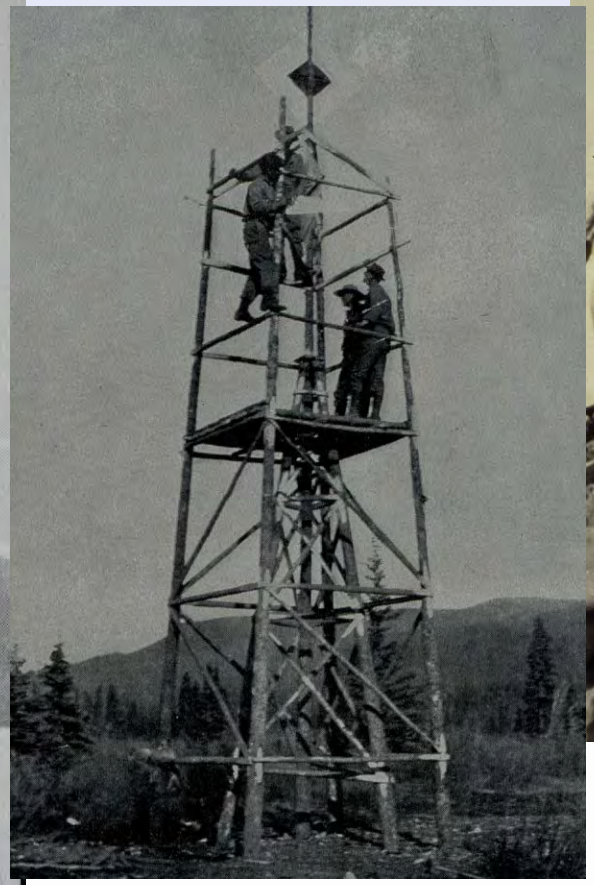
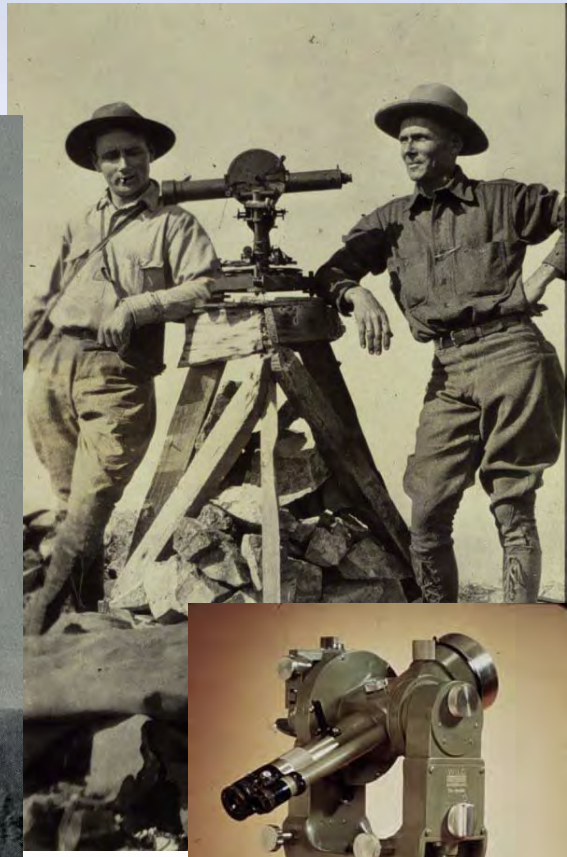
May 25, 2011

A Little History



Measuring Angles



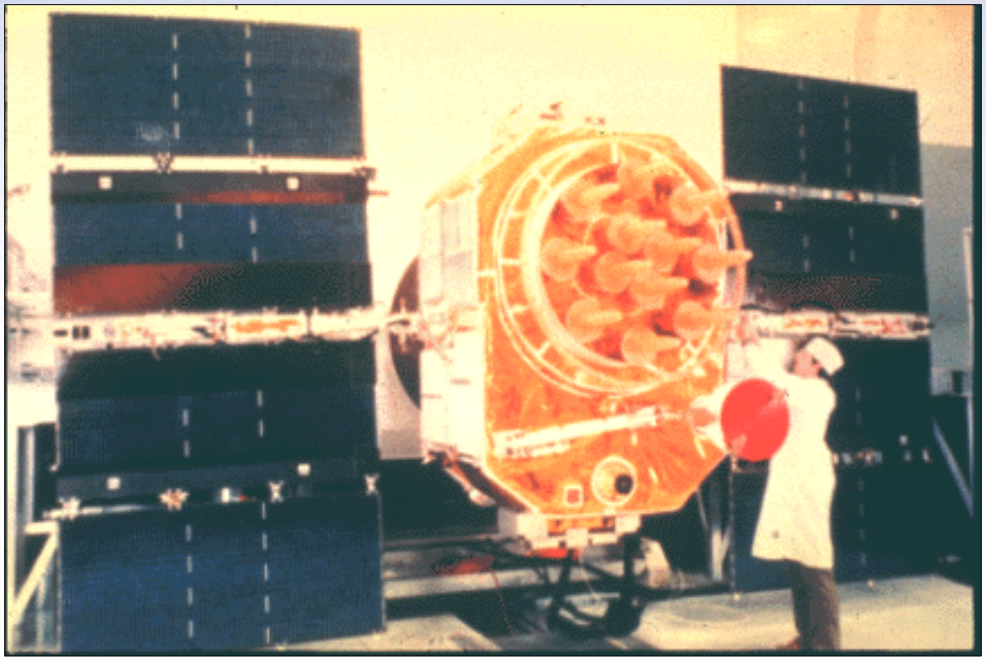


Distance Measurement

Electronic Distance

What is GPS?

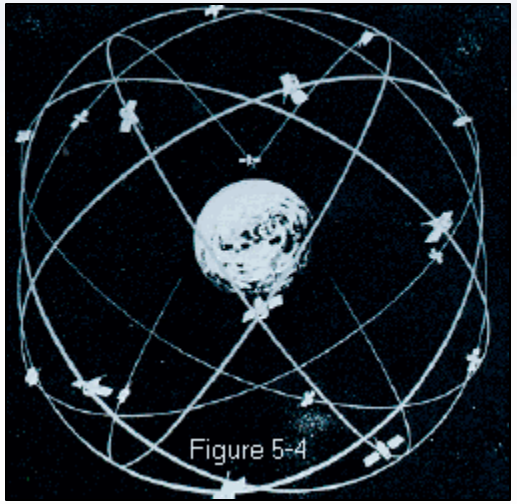
- A space-based timing and navigation system
- Owned and operated by the Department of Defense, i.e., military system
- First Launch in 1986
- Declared fully operational in 1995.

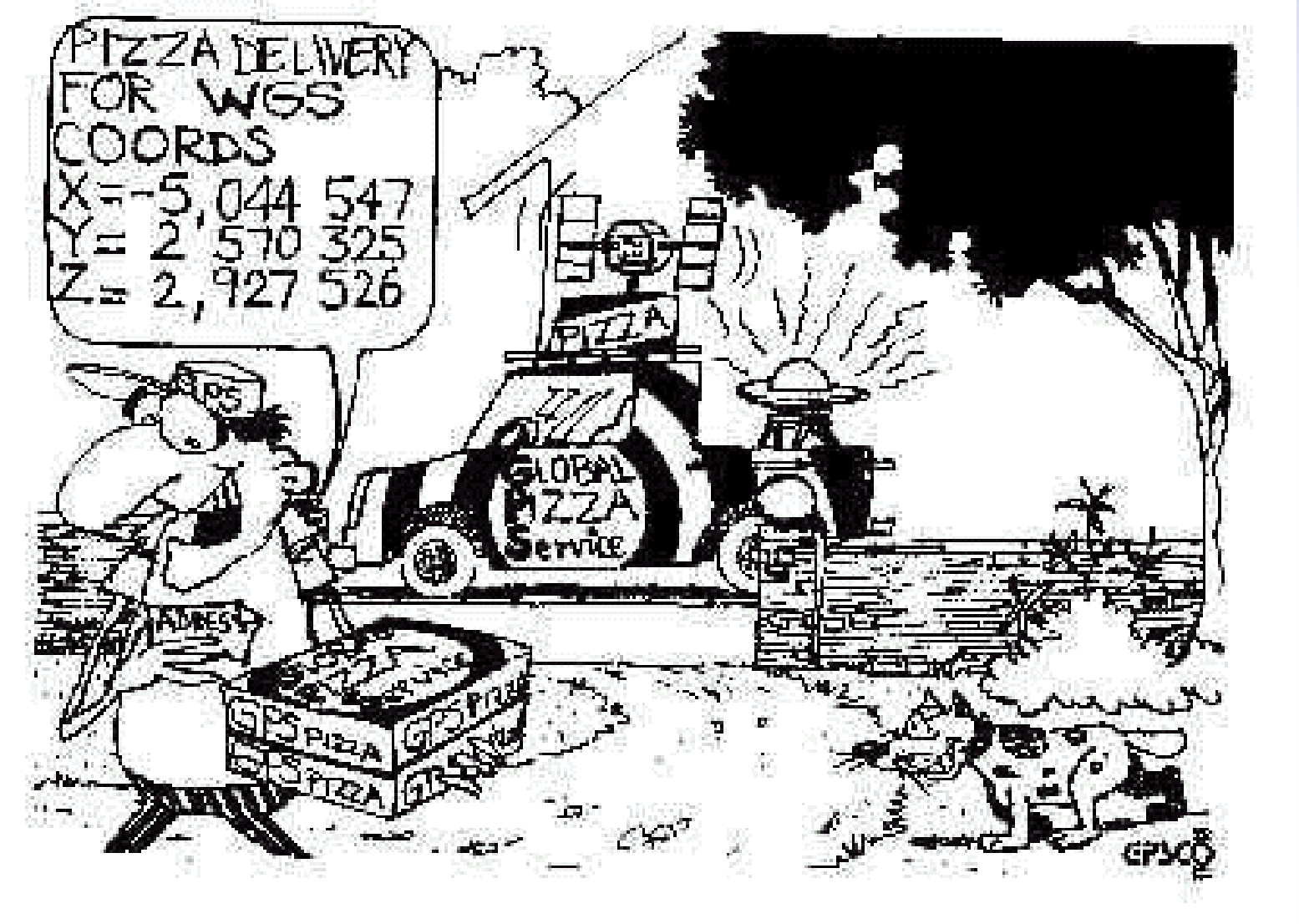


GPS Satellite (Block II)

GPS Characteristics

- 24 active Satellites, approximately 4 spares in orbit
- 6 Orbital planes inclined at 55 degrees
- 20200 km above the Earth's surface
- 12 hour orbit (in view 4 - 5 hours)
- Operate in a time frame such that they precess approximately 4 minutes each day (satellites rise that much earlier each day)
- Deigned to operate for about 7 - 8 years
- Broadcast on 2 frequencies (L1 & L2)

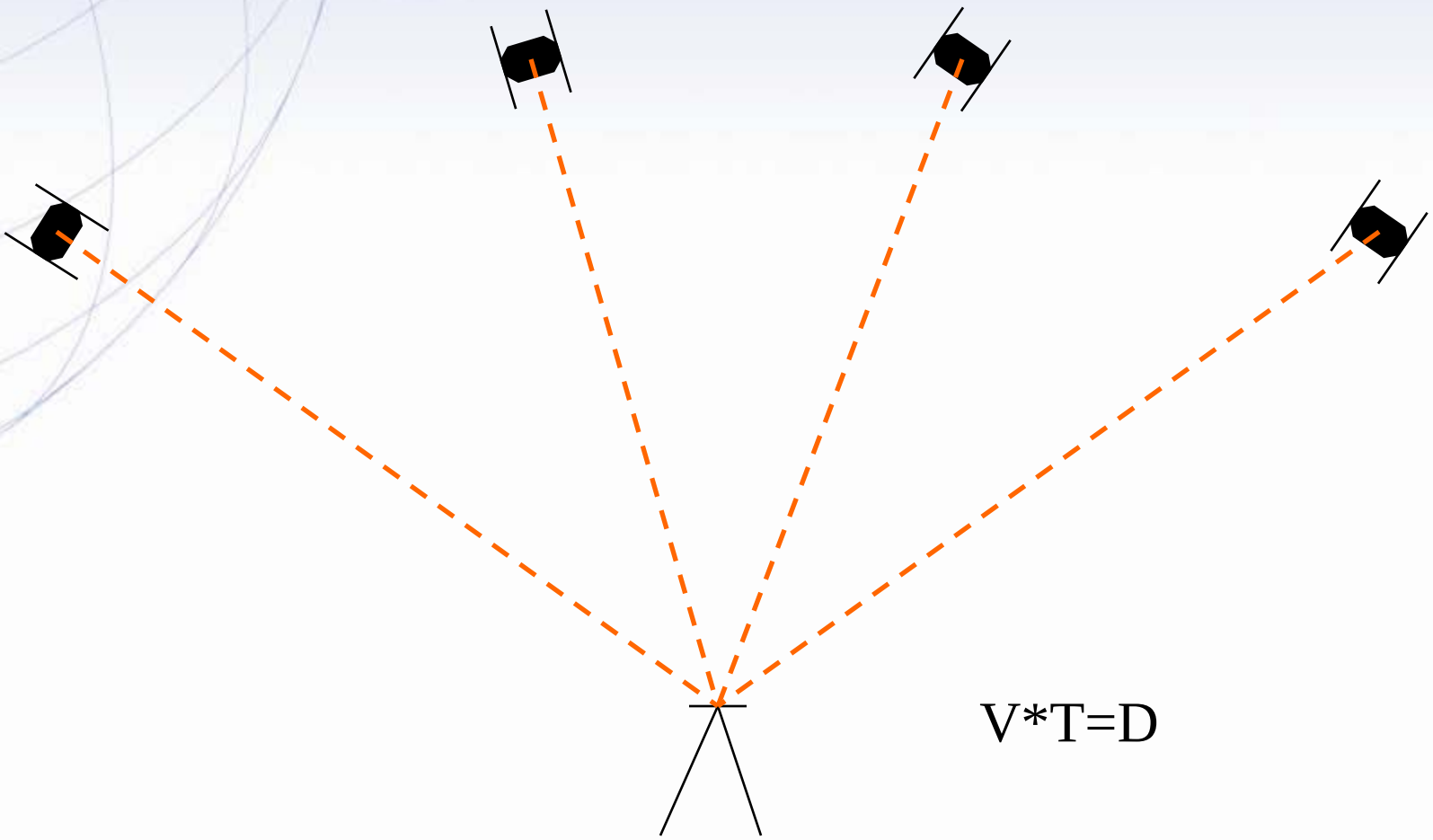



PIZZA DELIVERY FOR WGS COORDS
X=-5,044 547
Y= 2,570 325
Z= 2,927 526
PIZZA
GLOBAL PIZZA Service
ADDRESS
PIZZA
PIZZA
GPSOP

How GPS Positioning Works

- The basic navigation point position can be calculated like a resection in space
  - Satellites are like orbiting control stations
  - Vectors are measured to each satellite using time dependent code
- 4 satellites are required to solve for the 4 unknown parameters
  - Latitude
  - Longitude
  - Height
  - Time offset

GPS 101



Code and Phase Measurements

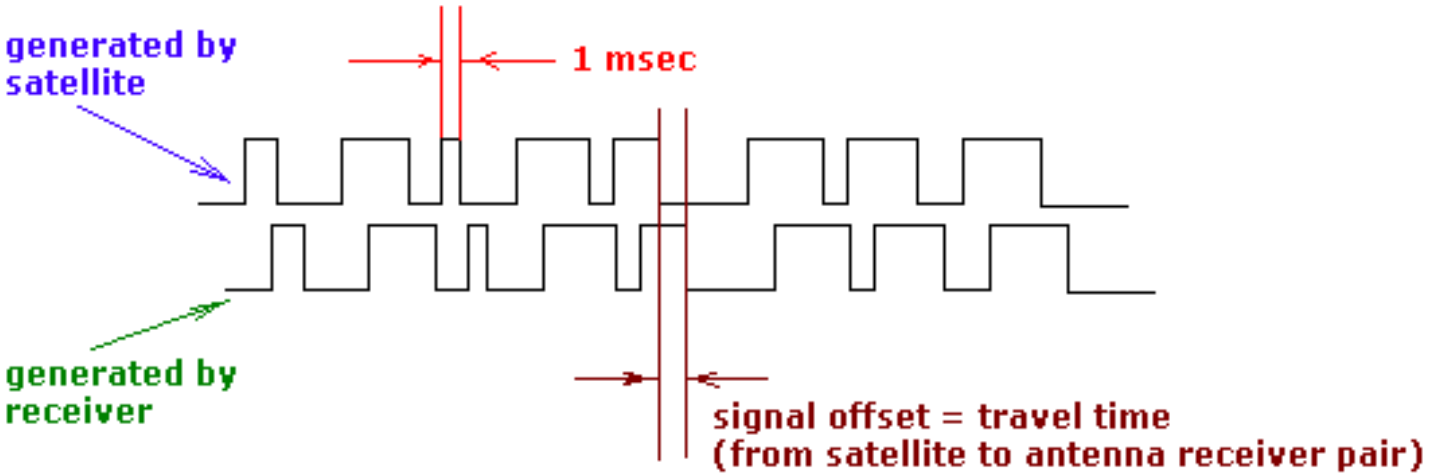
- The pseudorandom noise code for each satellite is transmitted via carrier wave
  - C/A Coarse Acquisition code
  - P Precise code
- Phase, the fractional portion of the carrier wave of the incoming signal is measured by the GPS receiver
- Satellites broadcast at 2 frequencies
- L1 - 1575.42 MHz with C/A & P code
- L2 - 1227.60 MHz with P code

How do we tell time?

C / A code - pseudo random noise code - code phase

Each satellite broadcasts its own unique code

This code is provided on L1 - 1575.42 MHz only



- cycle width is 1 msec
- at the speed of light, a microsecond equates to 300 meters of error

GPS Carrier Phase

- Signal wave lengths
  - L1 is 19 cm
  - L2 is 24 cm
- Receiver compares incoming phase of signal with a similar phase pattern it generates internally
- Measures fractional portion of incoming phase and determines the offset between the two phase patterns
- Since the carrier wave can be segmented more finely than C/A and P codes, it can yield millimeter level baseline determinations

Ambiguity

- Ambiguity is the unknown number of full wavelengths from the reference satellite to the antenna phase center
- Must be solved for to achieve centimeter accuracy
- Receiver keeps track of the subsequent number of wavelengths and the partial fractional wavelength measurements

Limitations

- Must have clear/unobstructed view of sky
  - Problematic in forest/canopy
  - Problematic in urban Canyon
- Interference from solar flares possible
  - Can make data from single frequency receivers unusable
  - Possible to mitigate effect with dual-frequency receivers

Error Sources

- Multipath
- Ionosphere
- Cycle slips and loss of lock
- Operator error

Multipath

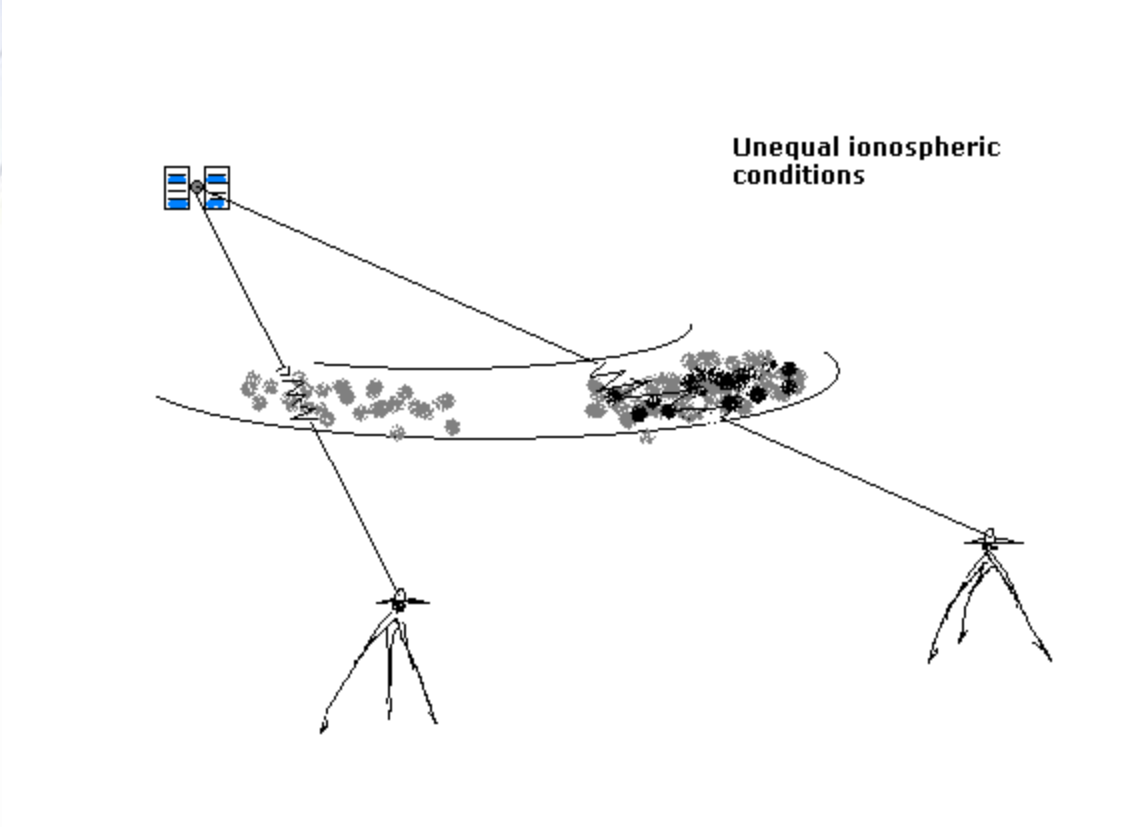
- Secondary signal / signal bounce
- Analogous to ghost-like quality of TV picture
- Yields an apparently longer distance to antenna position
- Difficult to detect and remove
- Precautions
  - locate antenna away from reflective surfaces
  - Observe longer sessions so that satellite geometry has a chance to change

Ionospheric Error

- Ionospheric delay =

  (local vertical delay)(obliquity factor)
- Dual frequency P-code users remove Ionospheric effects
- error remaining after differential ionospheric correction are minor for short baselines

Ionospheric Error



Cycle Slips and Loss of Lock

- Cycle slip
  - interruption of GNSS signal reception at antenna
  - undesirable - causes re-estimation of integer ambiguity
  - bigger problem when observation period is short
  - caused by RFI
  - L2 more susceptible since it is weaker than L1
- Loss of lock
  - signal interruption of longer duration than a slip such as when a satellite sets below horizon
  - caused by obstructions to line of site such as trees, buildings

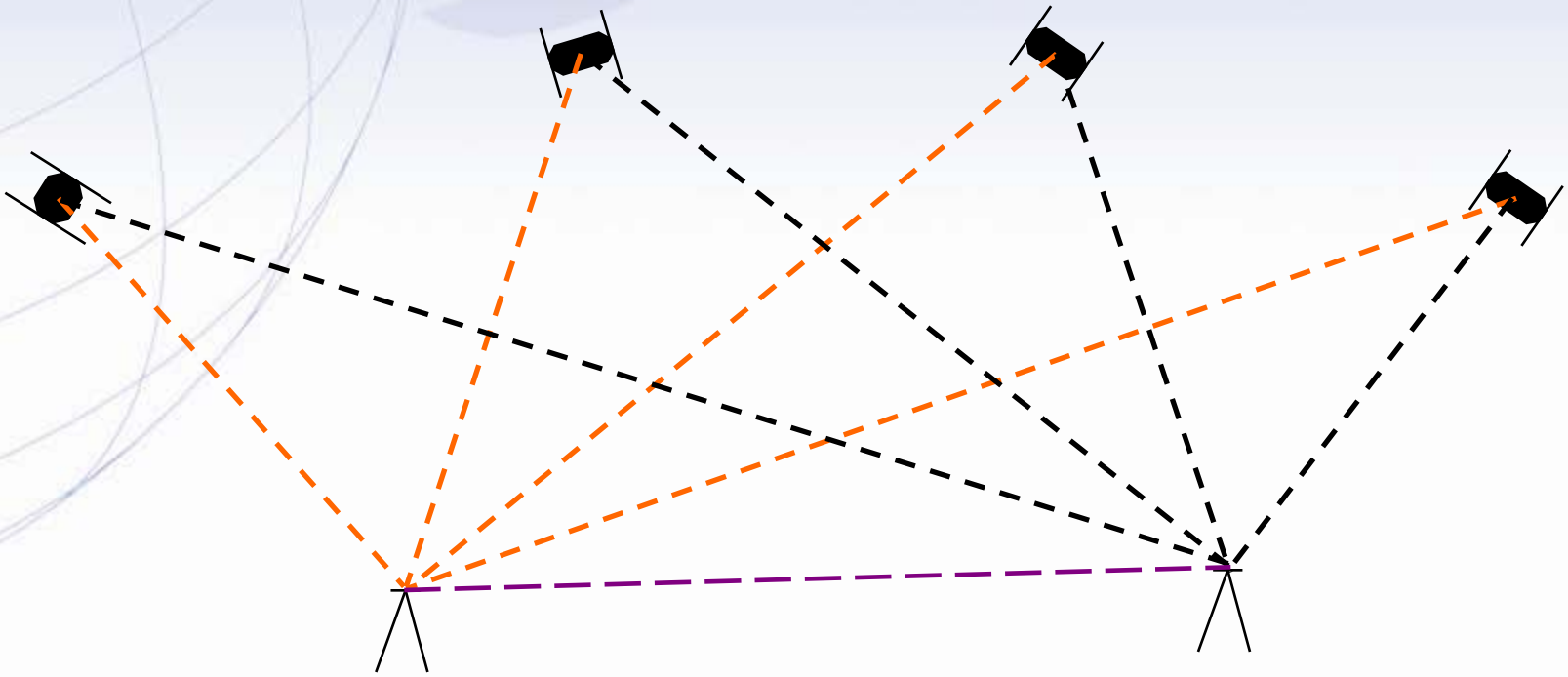
Operator Error

- Instrument (antenna height) measurement by operators
- Plumbing error
- Late arrival
- Bad scheduling
- Battery failure

Differential GNSS Surveying

- Requires at least 2 GNSS receivers operating simultaneously and tracking a minimum of 4 common satellites
- Receivers experience the same error sources generally, which cancel out, maintaining a relative accuracy result of 5 mm + 1ppm
- It's possible to determine the position of an unknown station with respect to a known station in this way
- Differential GNSS eliminates
  - Errors in satellite and receiver clocks
  - Eliminates error in satellite ephemeris
  - Minimizes the atmospheric effects

Differential GNSS



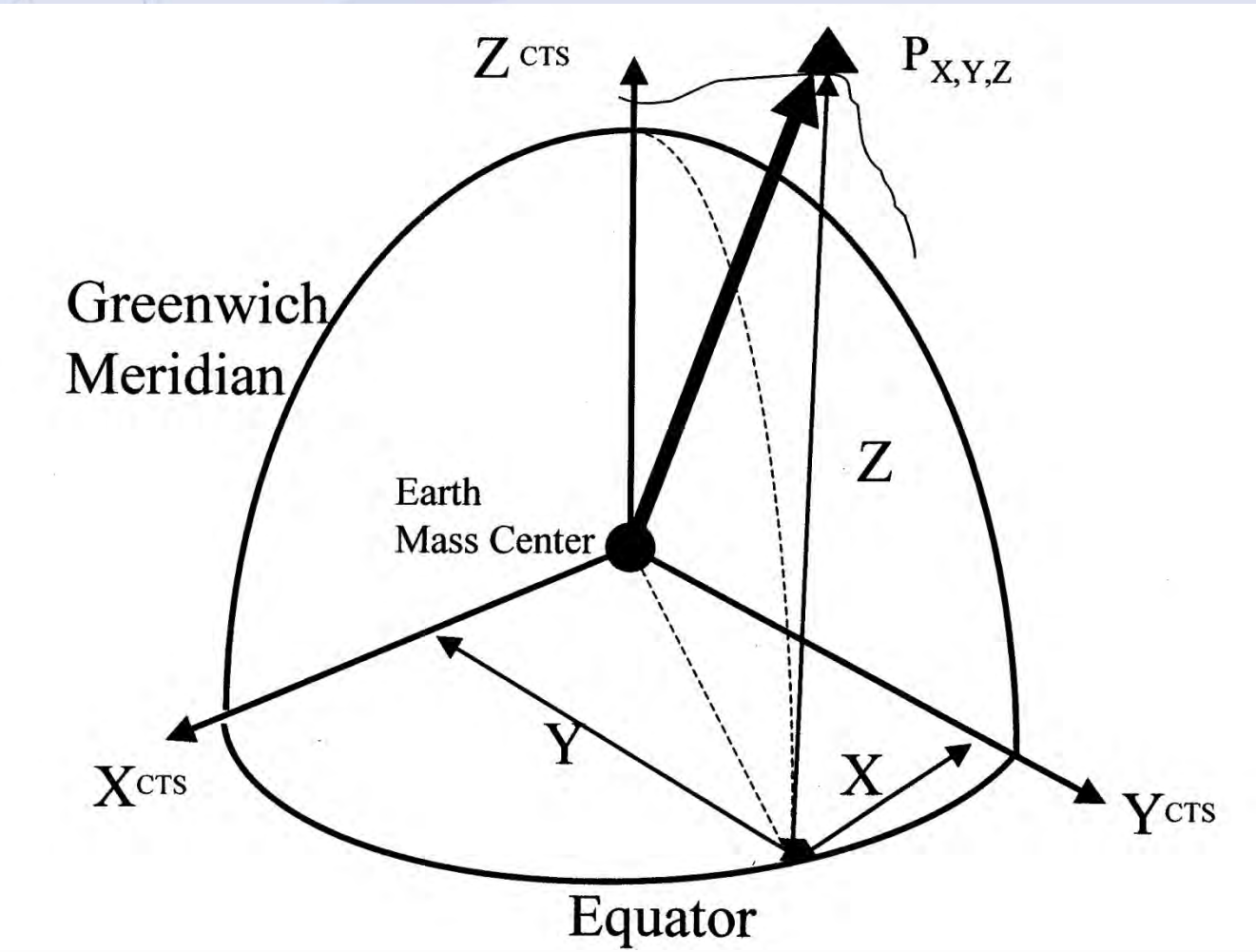
Types of GNSS Surveys

- Point Positioning
- Code Differential
  - Real-time
  - Post –processed
- Phase Differential
  - Static
  - Rapid Static
  - Post Processed Kinematic
  - Real-time Kinematic

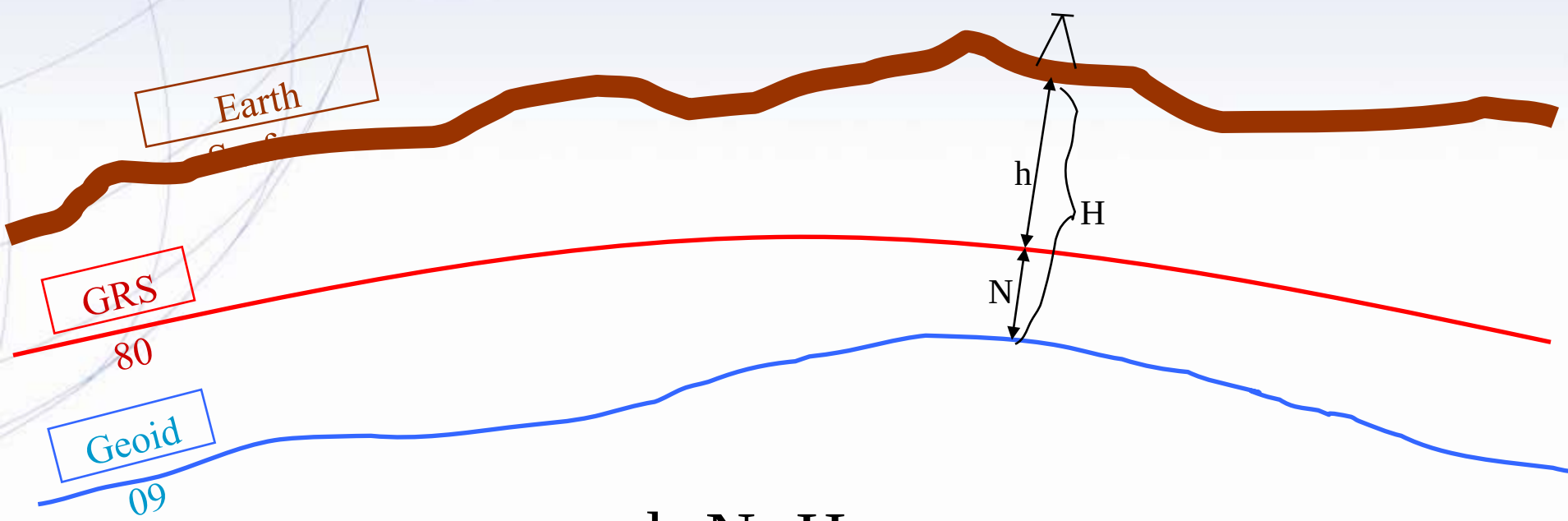
A Little on Coordinates

- GNSS does not measure in Latitude, Longitude and height above sea level
- Coordinate system is ΔX, ΔY, ΔZ from the earth center of mass.
- Coordinate delta's are transformed to Latitude, Longitude or Northing, Easting and a height above a reference ellipsoid.

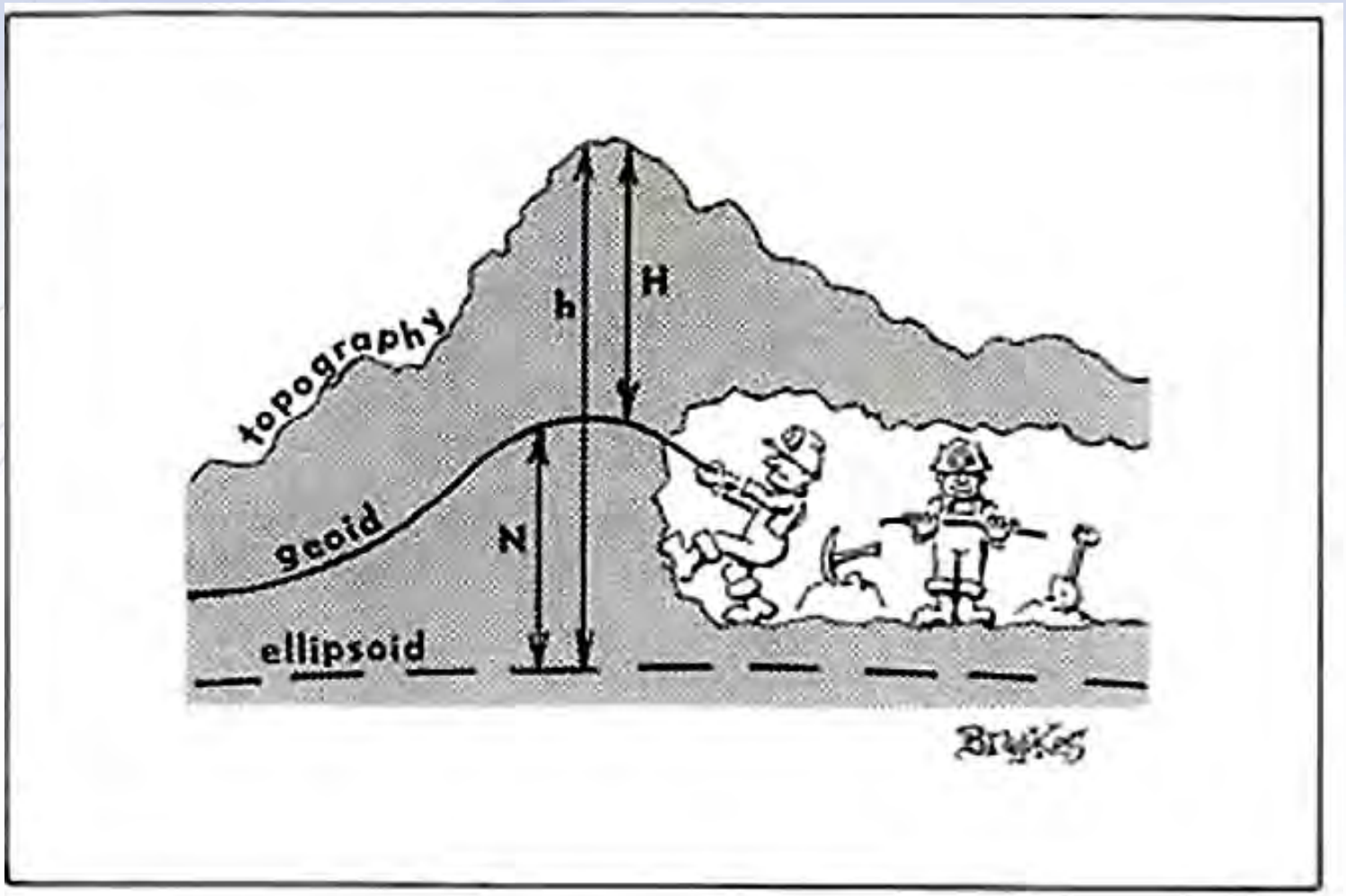
Earth Centered Earth Fixed (ECEF)



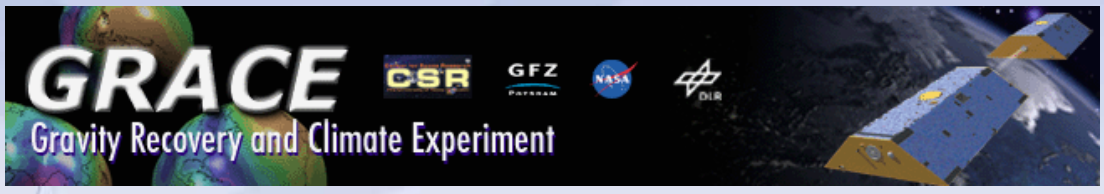
Orthometric Height
"Height above Sea Level"



h-N=H



In Search of the Geoid


GRACE
CSR
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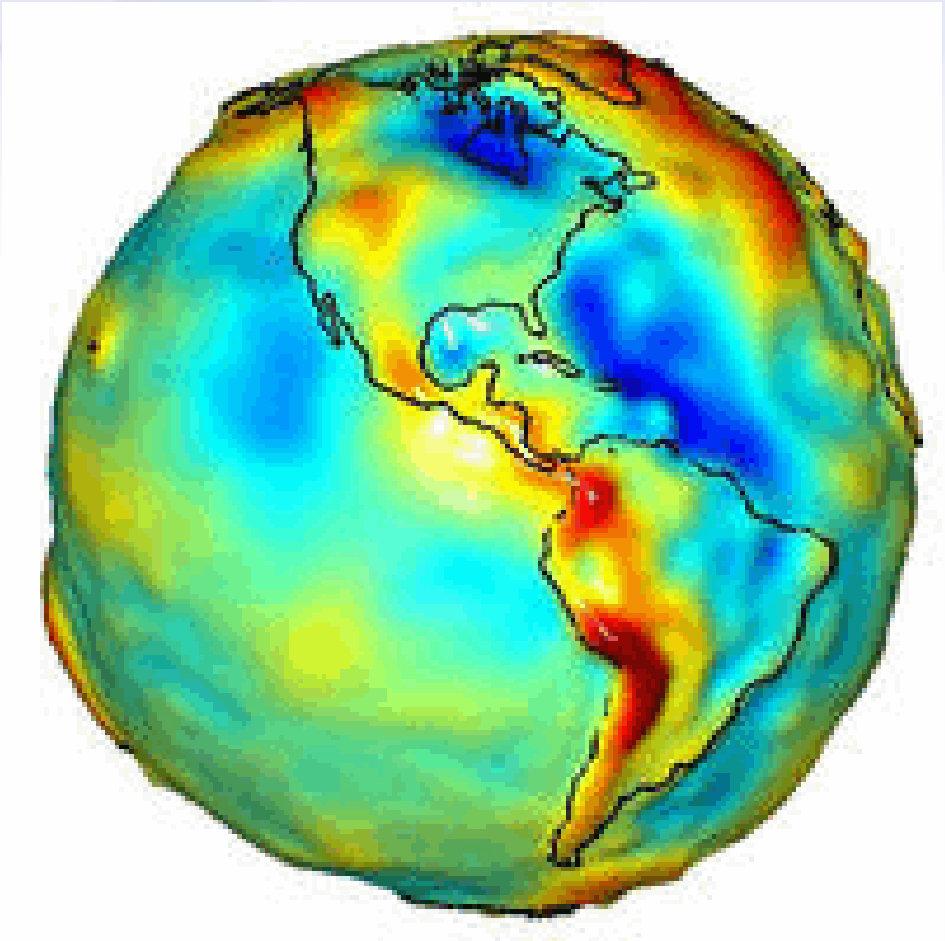
DLR
Gravity Recovery and Climate Experiment



Horizontal vs. Grid Distance

S=ellipsoidal distance

D= horizontal distance

R=mean earth radius

N=geoid height

H=orthometric height

h=ellipsoid height

K_{12}=line Grid Scale Factor (SF)

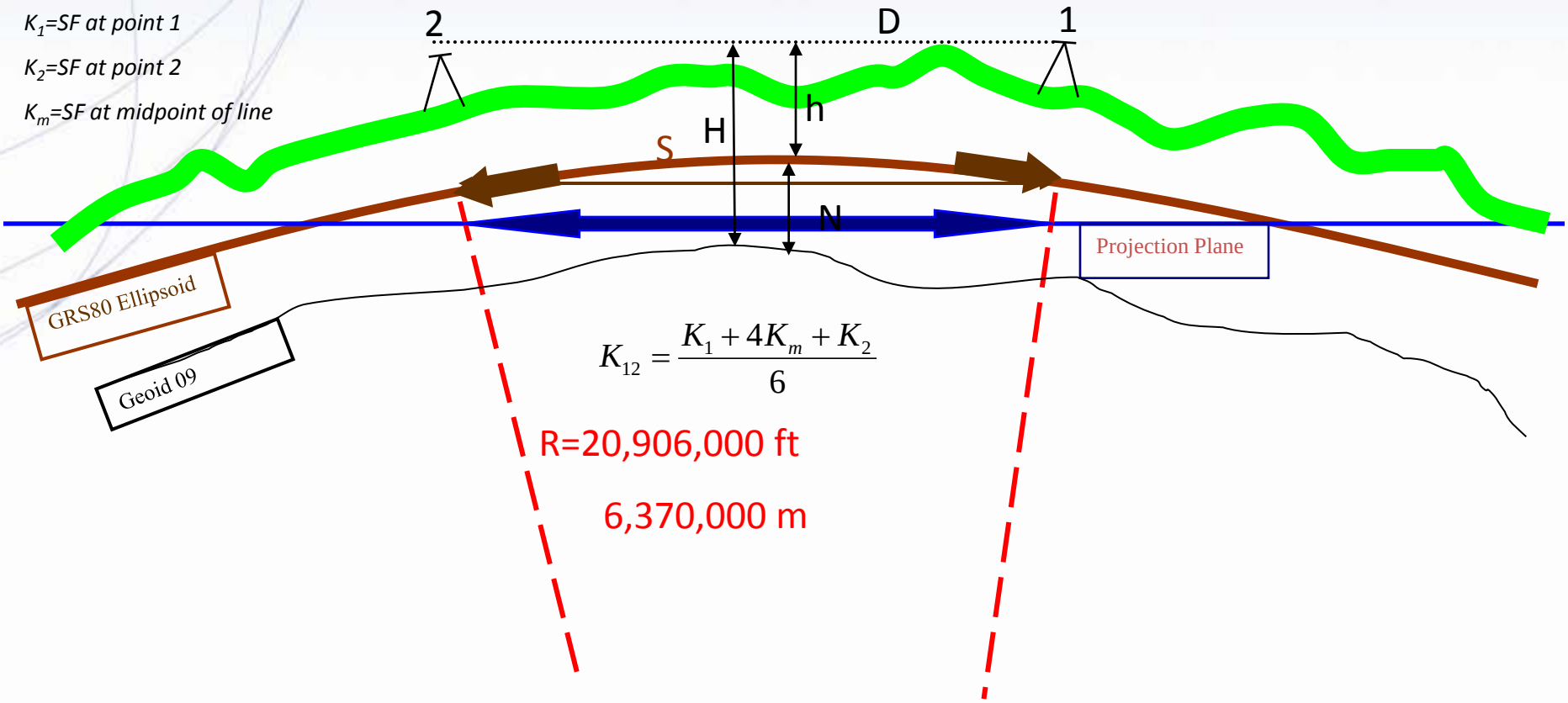
EF=elevation factor

K_1=SF at point 1

K_2=SF at point 2

K_m=SF at midpoint of line

$$S = D \times EF = D\left(\frac{R}{R+N+H}\right)$$



$$K_{12} = \frac{K_1 + 4K_m + K_2}{6}$$

R=20,906,000 ft

6,370,000 m

A Note About Conversions

- Be Careful when converting between feet and meters as there are two different systems of feet, the US Survey foot (.3048006096 m/ft and the International Foot (.3048 m/ft exact)
- 500,000 meters = 1640419.948 IF
- 500,000 meters = 1640416.667 SF
- Most States use the US Survey foot….but some use the International Foot

Augmentations

- Nationwide Differential GPS (NDGPS) (DOT-FRA)
- Wide Area Augmentation System (WAAS) (FAA)
- Real Time Networks (RTN)

What is VECTOR??

Vermont **E**nhanced **C**ORS & **T**ransmission **O**f **R**eal-time data

- Network of Continuously Operating GNSS Reference Stations.
- Provides access to the National Spatial Reference System (NSRS)
- Access available for post processing (Static) and Real-time (single base RTK).

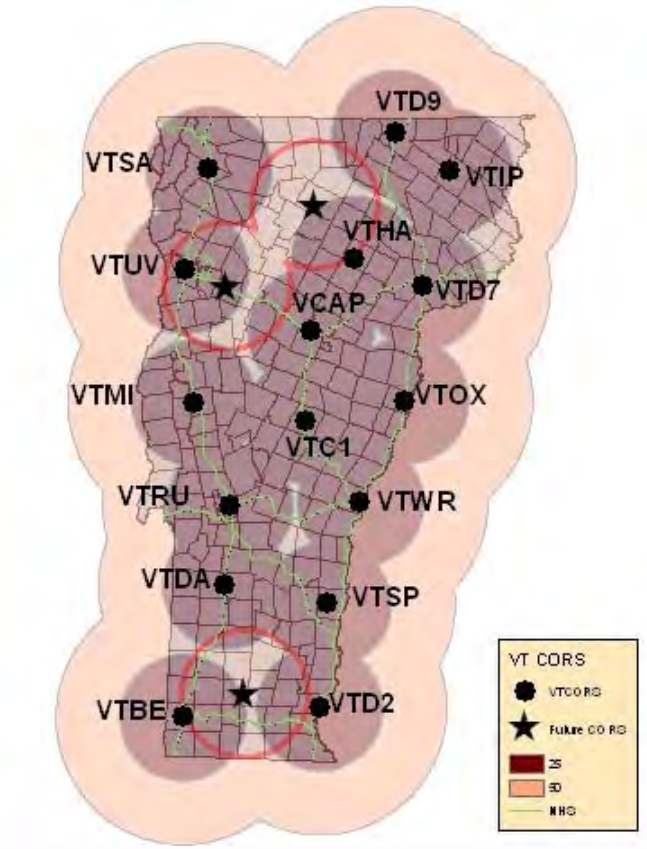
VECTOR

Site Criteria

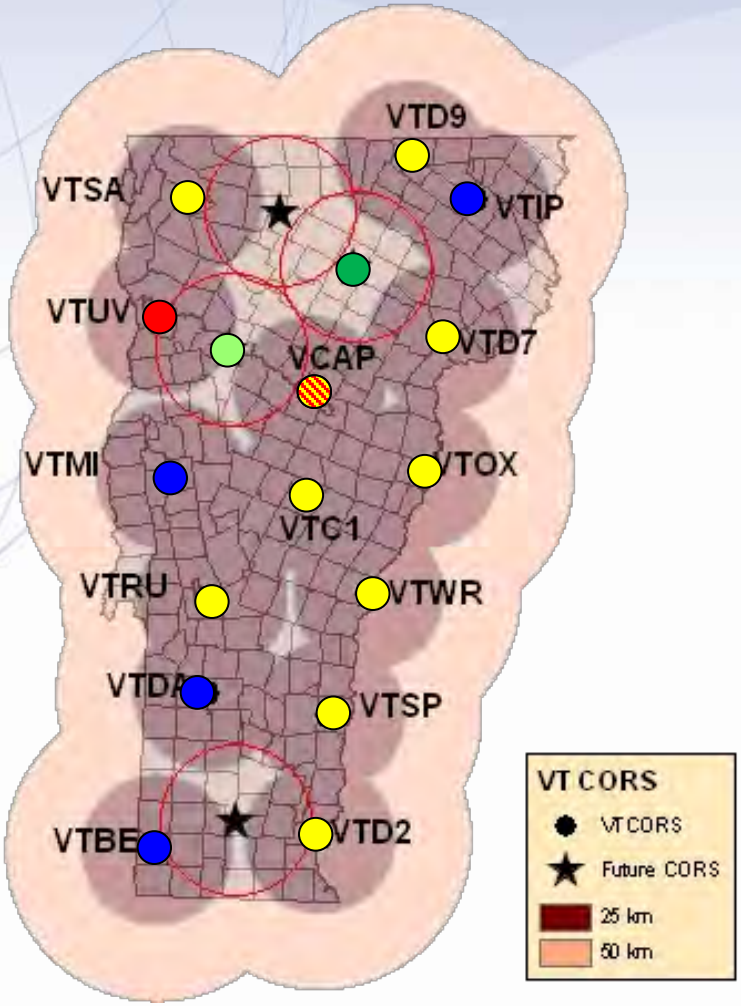
- 50 km spacing along Interstate
- Masonry building <= 2 story
- Secure location
- State owned
- Clear view to sky
- Stable/dedicated power source
- High speed internet connection
- Antenna location < 100 meters from receiver location

CORS Network Background

- Existing network installed in 2007
- All but 2 are GNSS receivers
- Four additional CORS will be added in 2010
- 40km-50km network spacing after full build out
- RTK data stream available via NTRIP (Single Base)



VECTOR Expansion

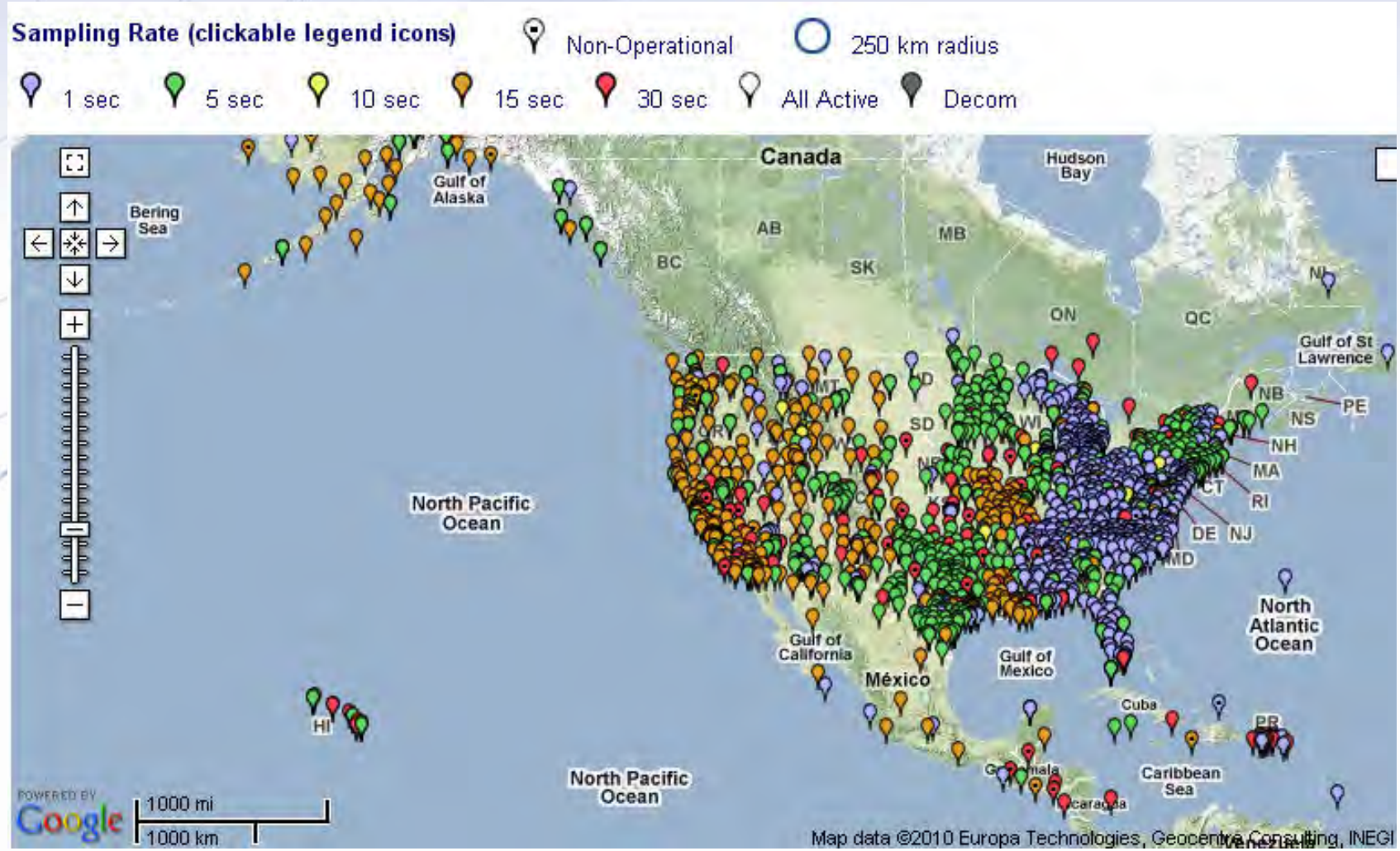


- 1996 - VCAP
- 2004 - VTUV
- 2006 – VTD2, VTSP, VTWR, VTOX, VTD7, VTD9, VTC1, VTSA, VTRU, (VCAP Upgrade)
- 2008 – VTBE, VTDA, VTMI, VTIP
- 2010 – VTHA
- 2011 - VTRI

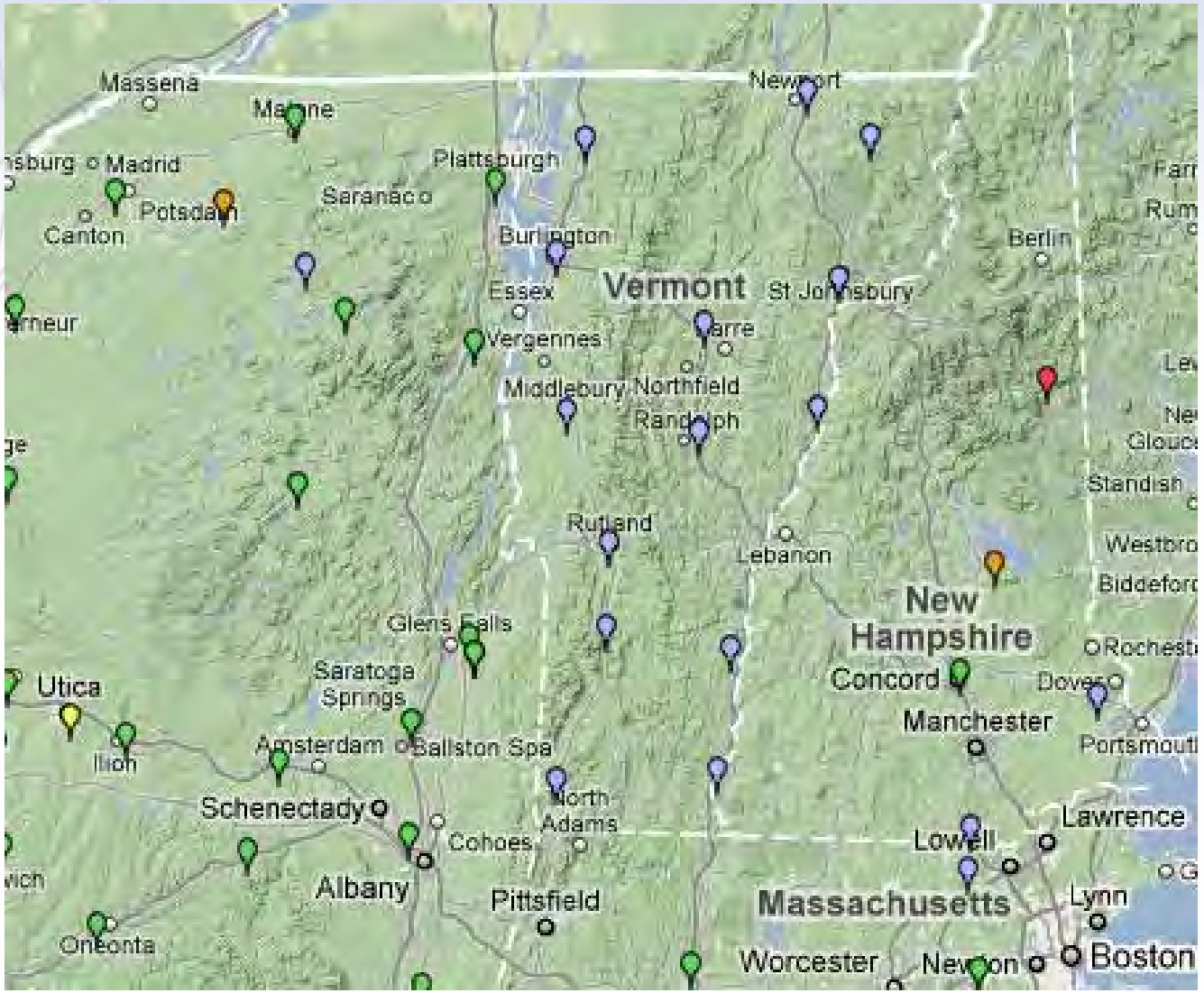
- Two stations will be added in 2011 to complete the network - Dover and Eden

1635 National CORS

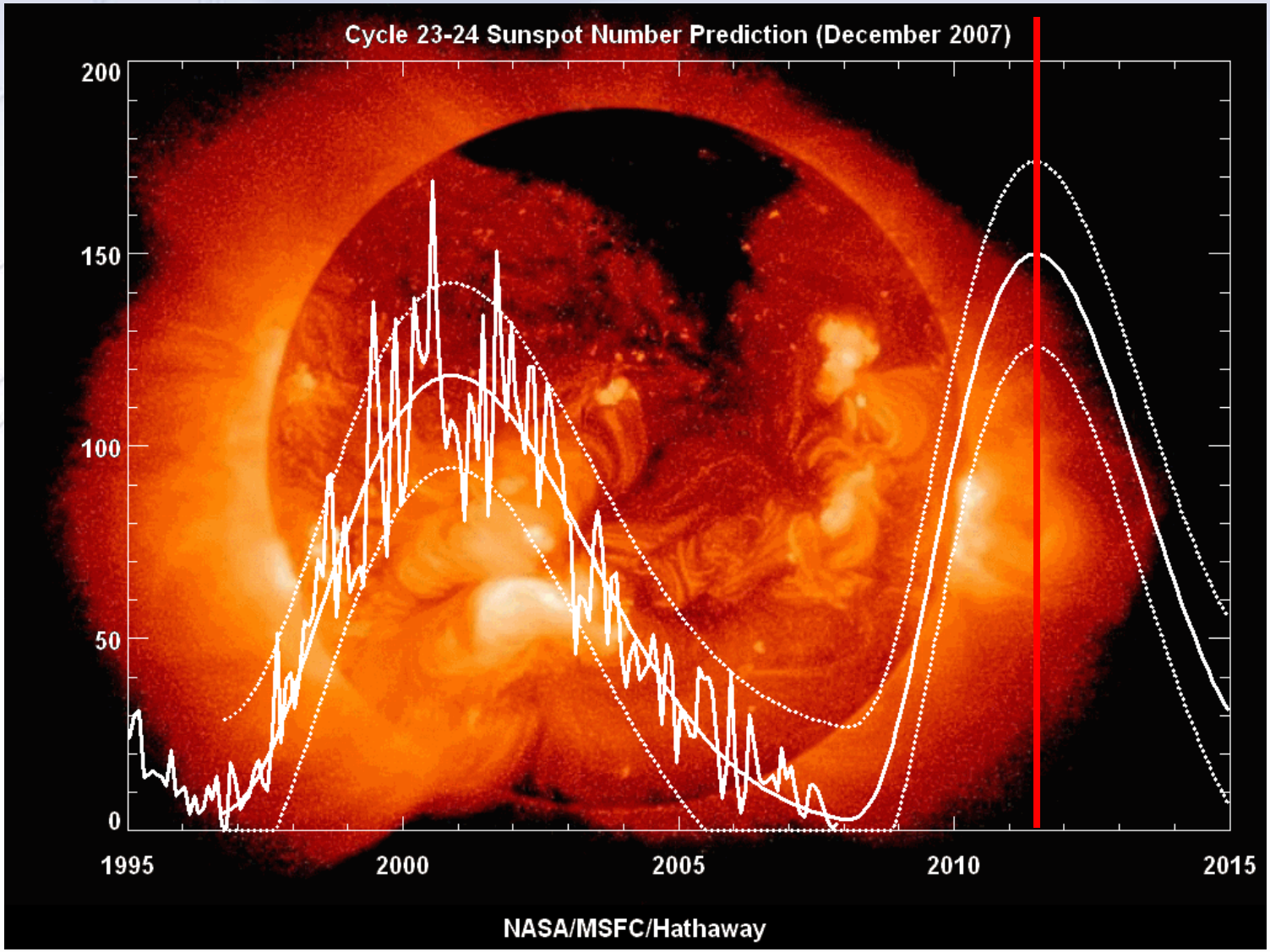
As of 05/12/11



National CORS in our Area



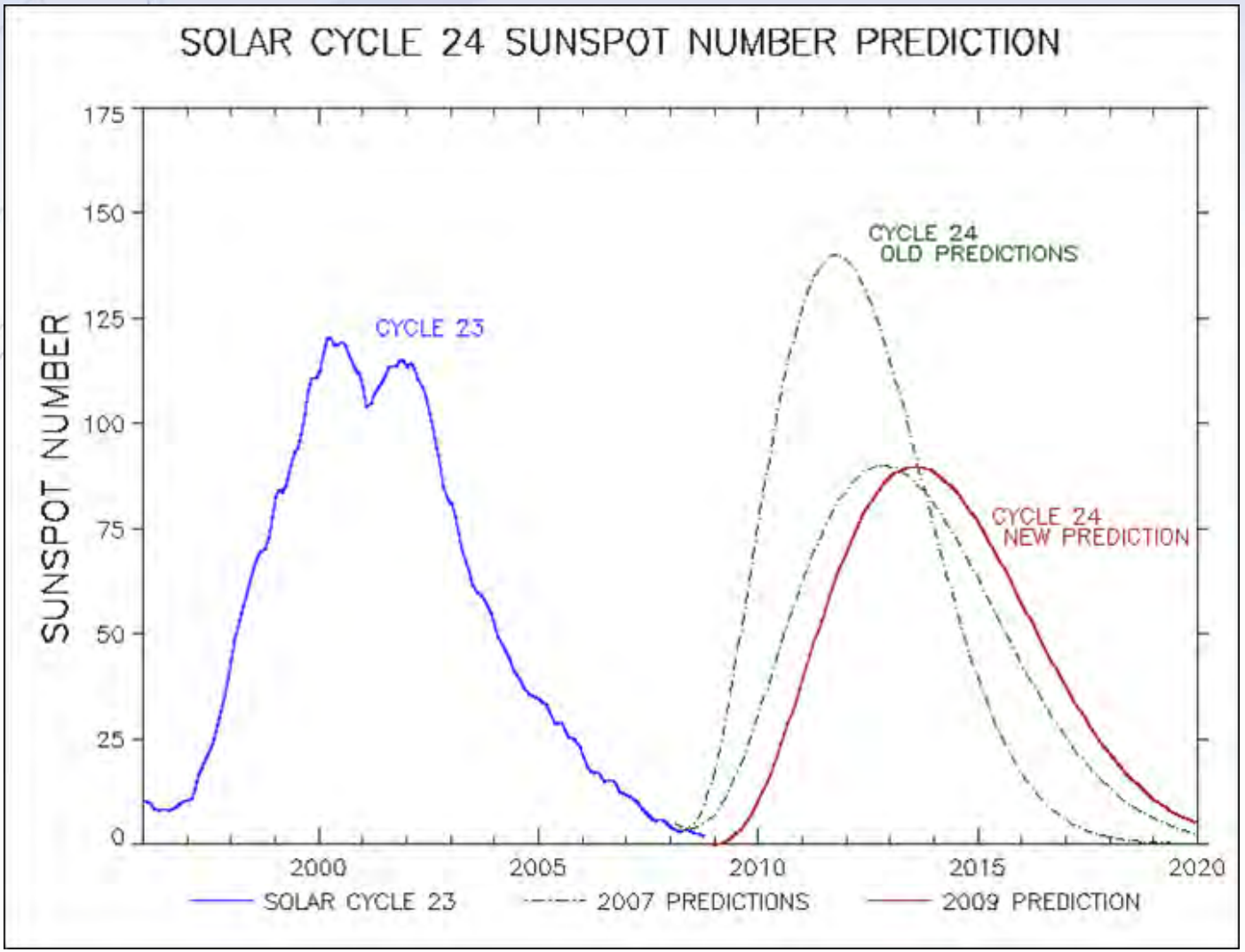
Solar Cycle 24 and GPS



What are the effects on GPS and augmentation systems?

- Creates disturbances in the ionosphere
  - Loss of lock due to ionospheric scintillation
  - Radio disruption
  - Cell phone disruption
  - Power grid outages
  - Surface charging and resulting damage to satellites

Current Predictions (the good news)



http://www.swpc.noaa.gov/

Vermont Geodetic Survey - CORS | NOAA / NWS Space Weather Pred... | Mozilla Firefox Start Page

National Weather Service
Space Weather Prediction Center

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Top News of the Day:
May 2, 2011 - The 2011 Space Weather Enterprise Forum (SWEF) will be held June 21, 2011.

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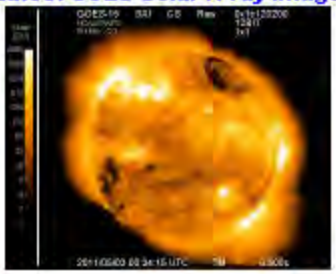
Latest GOES Solar X-ray Image

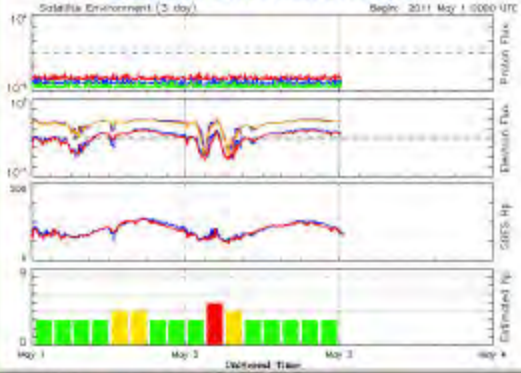


NOAA Scales Activity

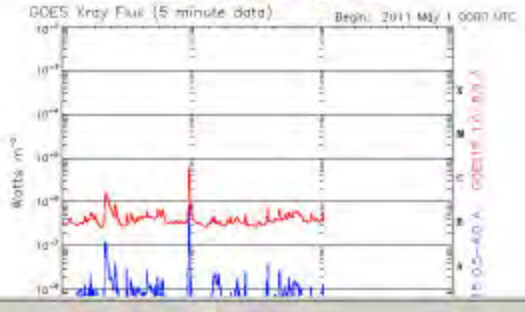
Range 1 (minor) to 5 (extreme)

NOAA Scale	Past 24 hours	Current
Geomagnetic Storms *	none	none
Solar Radiation Storms	none	none
Radio Blackouts	none	none

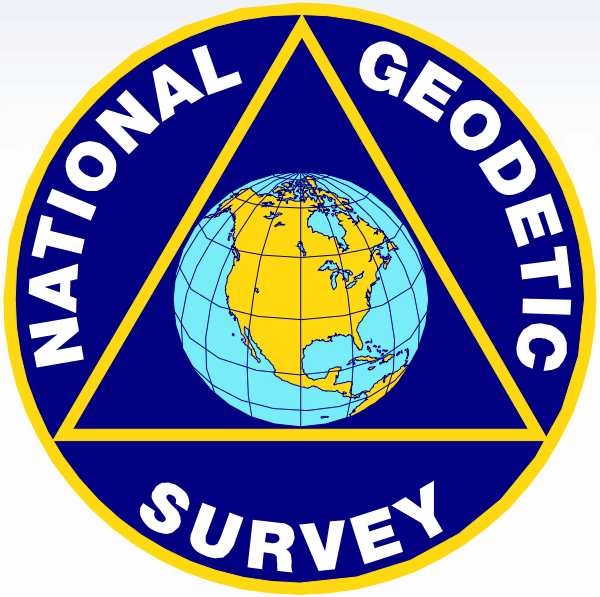
Satellite Environment Plot



GOES Solar X-ray Flux



GOOD COORDINATION BEGINS WITH GOOD COORDINATES



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