Ground-Based GPS Observations of Turbulence

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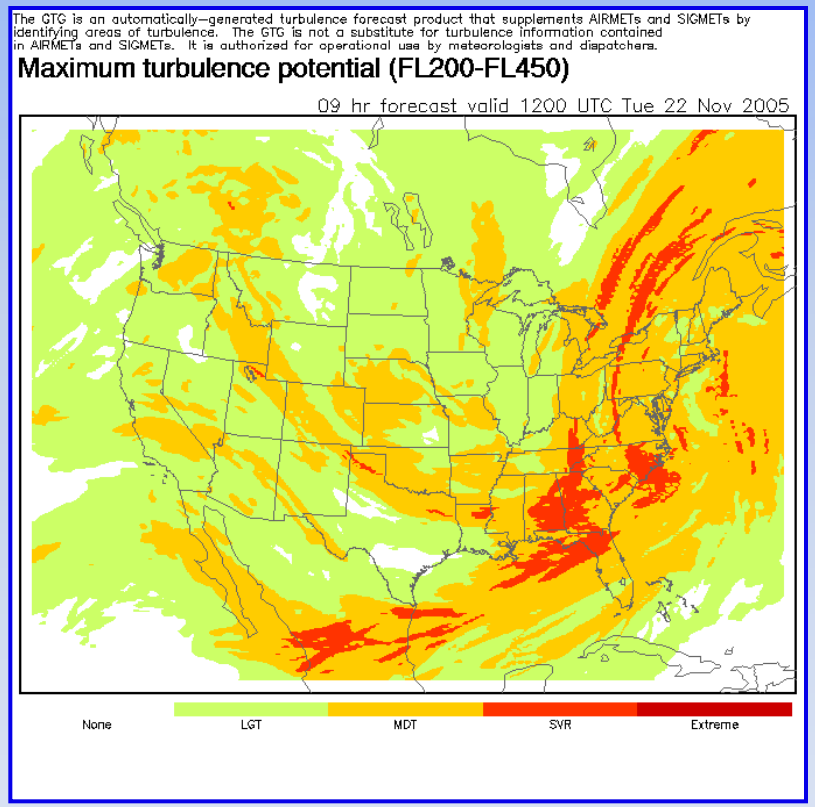
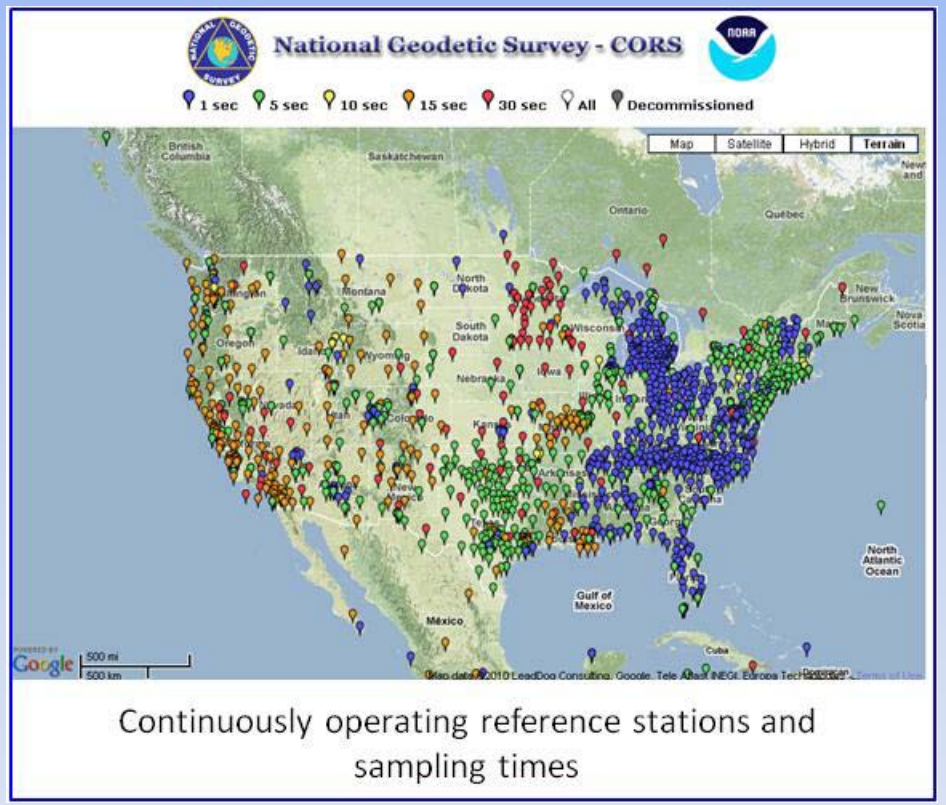
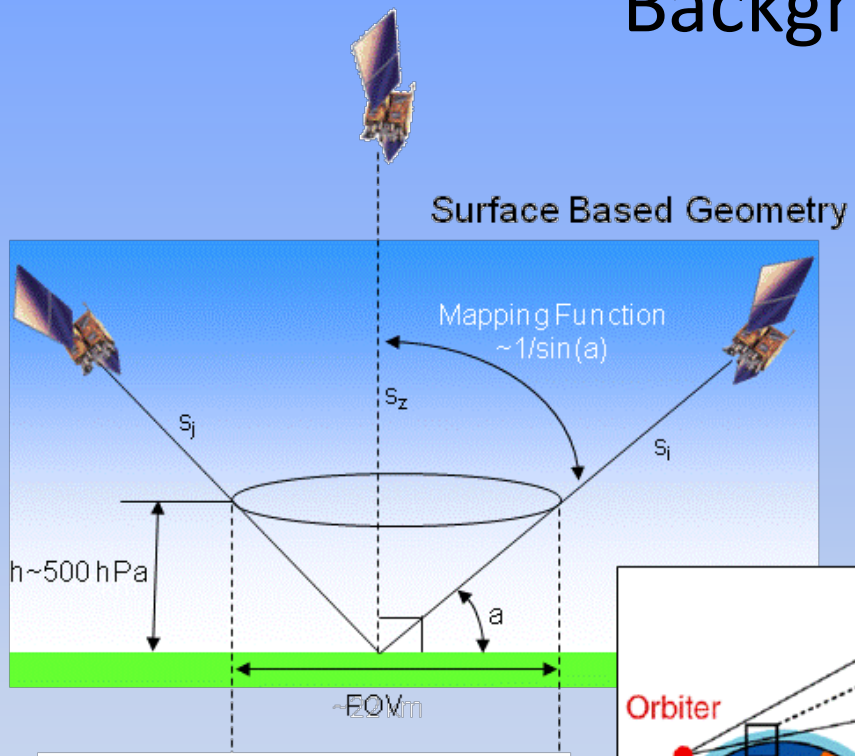




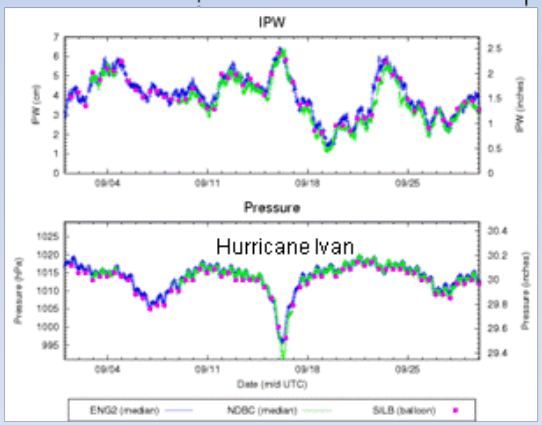
Background



In both cases, the fundamental measurement is

$$\Delta s = 10^{-6} \int N(s)ds$$

N(s) the refractivity of the atmosphere along the path of the radio signal $N(s) = 10^6 (n(s)-1)$.



Space Based Geometry

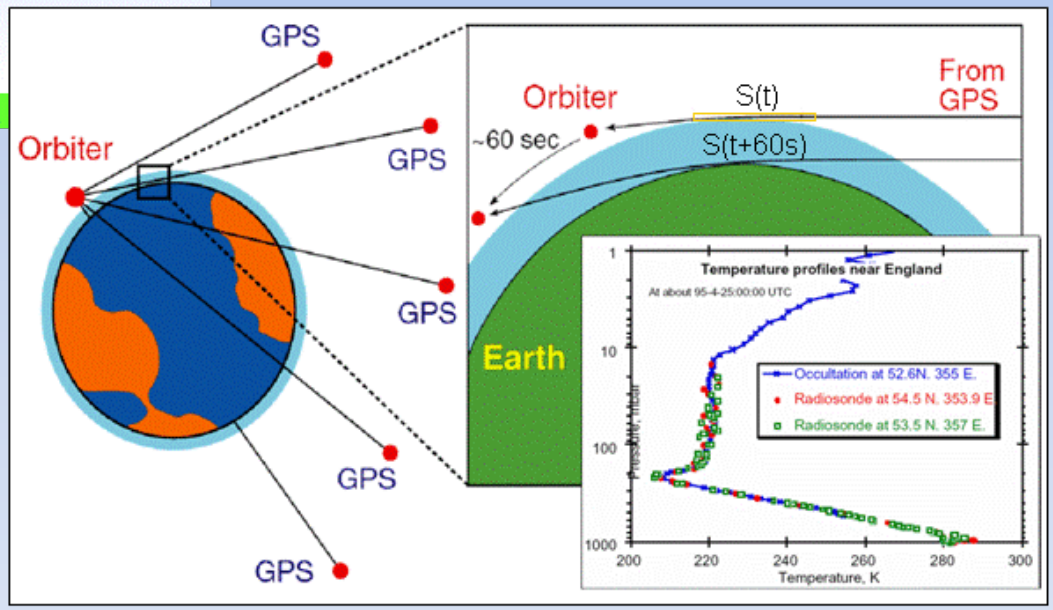
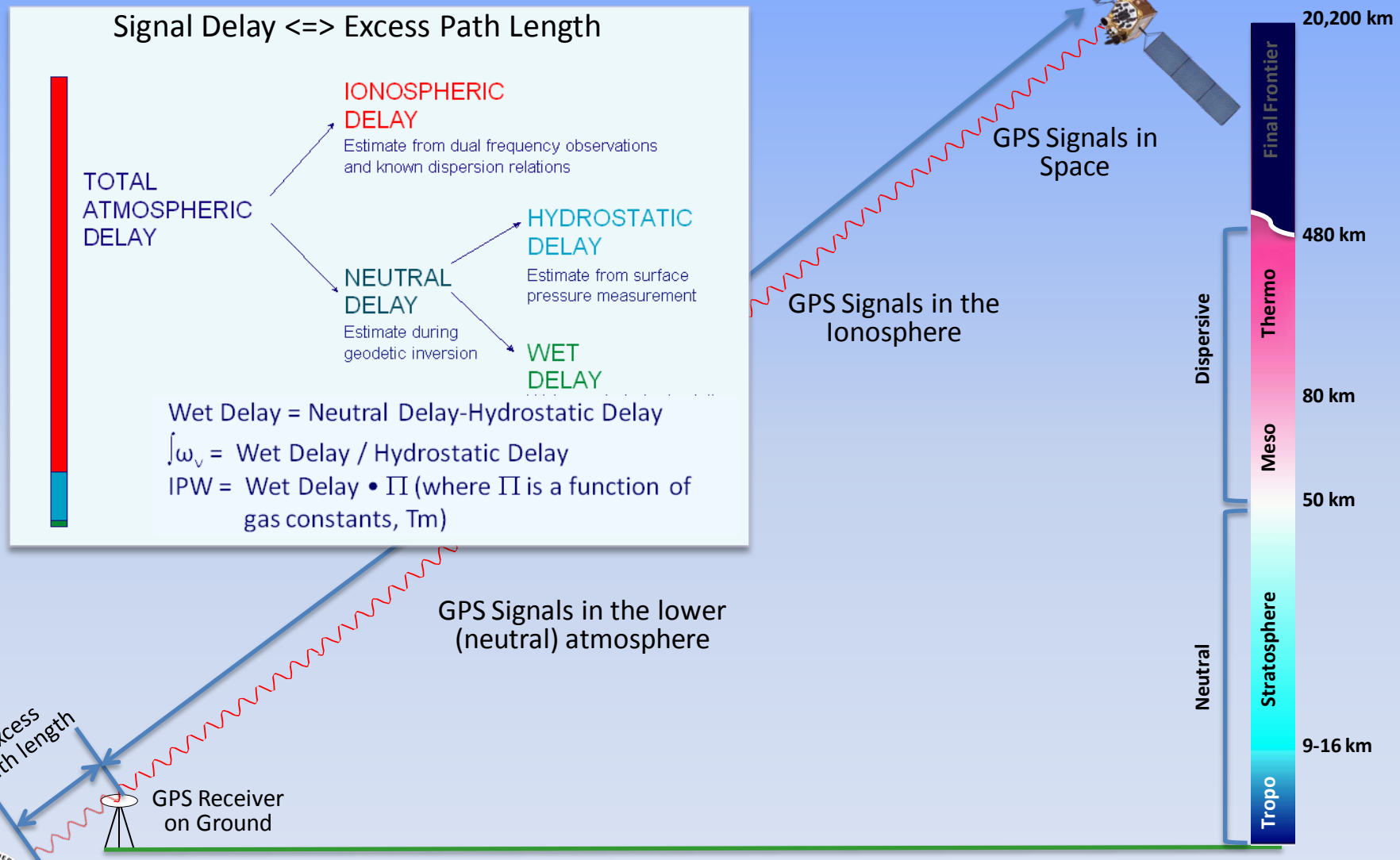


Illustration above courtesy of T. Yunk, NASA JPL.

GPS Metrology



Overview

- The tropospheric signal delay caused by the refractivity of neutral atmosphere is routinely estimated as a free parameter in the calculation of GPS antenna position.
- Power spectrum analysis of fluctuations in the neutral signal delay indicate that they exhibit a power law dependence that is characteristic of Kalmogorov turbulence.
- The magnitude of these fluctuations (commonly expressed in terms of C_n^2 the "roughness" or scale of the turbulence [Tatarskii, 1961]) is a function of site-specific parameters including latitude, elevation and local geomorphology.

Discussion

- It should be possible to search the characteristics of the zenith neutral delay at each station in real-time for evidence of “elementary “ turbulence within the FOV of the fixed GPS/GNSS antenna (~ 10 km) and
  1) transmit this information to a control center to provide improved ATC situational awareness
  2) use this information with other observations, analyses or predictions to provide improved turbulence warnings and forecasts.
- Let’s look at the pros and cons of this approach.

Pros

- This approach takes advantage of the positive attributes of all GPS/GNSS techniques:
  1) all weather operability
  2) arbitrary temporal and spatial resolution over land
  3) highly leveraged
  4) dual/multiple-use
  5) low cost, high reliability, easy maintenance
  6) no scientific breakthroughs required.
- Acknowledges the fundamental physical limitations of all (ground & space-based) GPS/GNSS techniques.
- Accuracy of ZTD measurements are easy to verify.

Cons

- The observations by themselves contain no information about where changes in refractivity occur along the path of the radio signal.
- Accuracy of retrievals or products strongly depend on accuracy of assumptions.
- This suggests that variational assimilation of C_n^2 (roughness or scale) into a model may be the most straightforward and least risky way to analyze these observations.
- Depending on what is being estimated, assumptions may be very difficult to verify.

Conclusions

- When it comes to aviation weather applications, GPS is “low hanging fruit.”
- It doesn’t do everything, but because of the remarkable characteristics of the system, it has potential applications in lots of unanticipated areas like monitoring turbulence.
- The sizable investment that DOD and DOT have and continue to make in GPS (e.g. Block III, WAAS, LAAS, ADS-B) provides us with opportunities to milk everything we can out of this tool *at low cost and risk*.