Navigation Performance of Global Navigation Satellite Systems in the Space Service Volume

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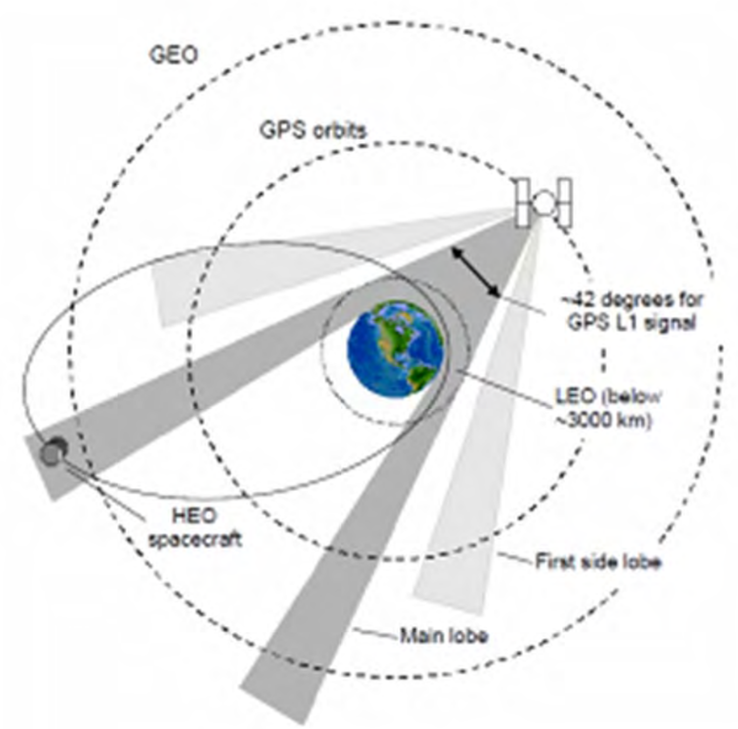
Objectives

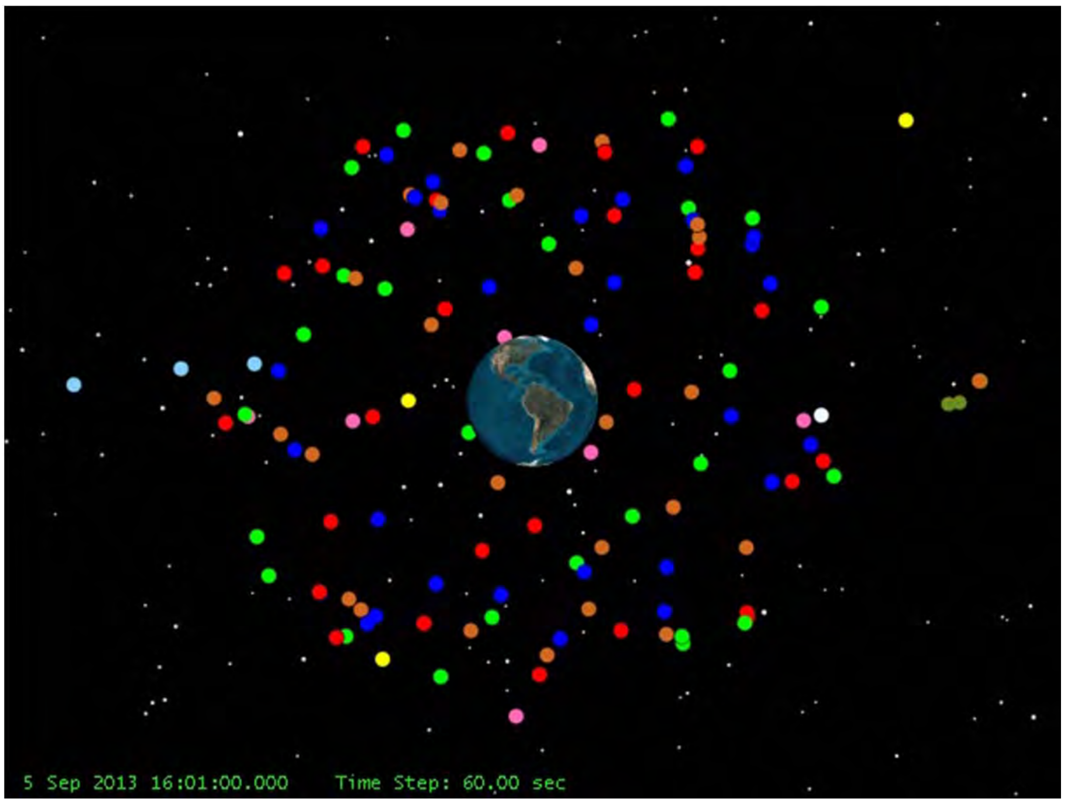
- GPS has been used for spacecraft navigation for many years
- In support of this, the US has committed that future GPS satellites will continue to provide signals in the Space Service Volume
- NASA is working with international agencies to obtain similar commitments from other providers
- In support of this effort, I simulated multi-constellation navigation in the Space Service Volume

Terrestrial and Space Service Volumes

Geometry of Reception of GNSS Signals by Satellites



GNSS Satellites Considered



- GPS
- Galileo
- GLONASS
- Beidou (MEO)

- WAAS
- EGNOS
- SDCM
- Beidou (GEO/IGSO)
- QZSS

Navigation Satellites Considered

- Global Positioning System (GPS)
- Galileo
- GLONASS (Global Navigation Satellite System)
- Beidou
- Satellite Based Augmentation Services (SBAS)

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- Wide Area Augmentation Service (WAAS)
- European Geostationary Navigation Overlay Service (EGNOS)
- System of Differential Correction and Monitoring (SDCM)
- Quasi Zenith Satellite System
- GPS Aided Geo Augmented Navigation system (GAGAN)

Previous Work

- I presented work on signal availability in the Space Service Volume for the various Global Navigation Satellite Services and for combinations of the systems in two presentations at ION ITM 2013
  - 'Individual Global Navigation Satellite Systems in the Space Service Volume', D. A. Force
  - 'Combined Global Navigation Satellite Systems in the Space Service Volume', D. A. Force and J. J. Miller

Current Work

- In this presentation, I extend the work to examine the navigational benefits and drawbacks of the new constellations
- A major benefit is the reduced geometric dilution of precision (GDOP). I show that there is a substantial reduction in GDOP by using all of the GNSS constellations
- The increased number of GNSS satellites broadcasting does produce mutual interference, raising the noise floor. A near/far signal problem can also occur where a nearby satellite drowns out satellites that are far away.
  - In these simulations, no major effect was observed

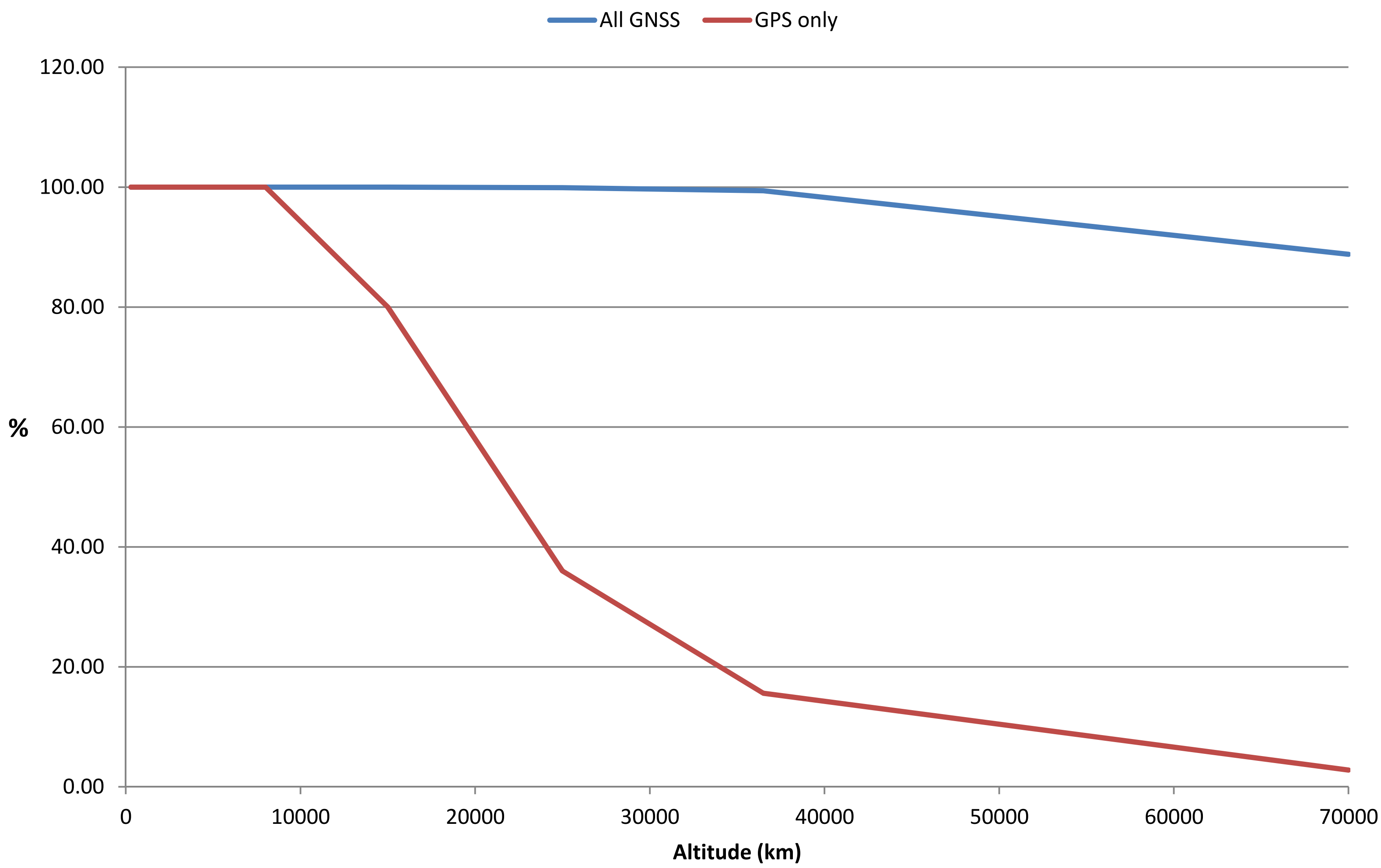
Assumptions

- L1 beams used
  - Most commonly implemented
  - Narrower beam makes this the conservative choice
- GPS beam taken as 23.5°, Galileo beam taken as 22°, GLONASS and Beidou MEO satellites assumed to use 23.5° beams
- WAAS and EGNOS use a 9°beam, which I assume for SDCM, QZSS, GAGAN and Beidou GEO and IGSO satellites, with SDCM beam tilted 7° toward the north
- GLONASS FDMA assumed; no interference with other L1 systems due to frequency offset

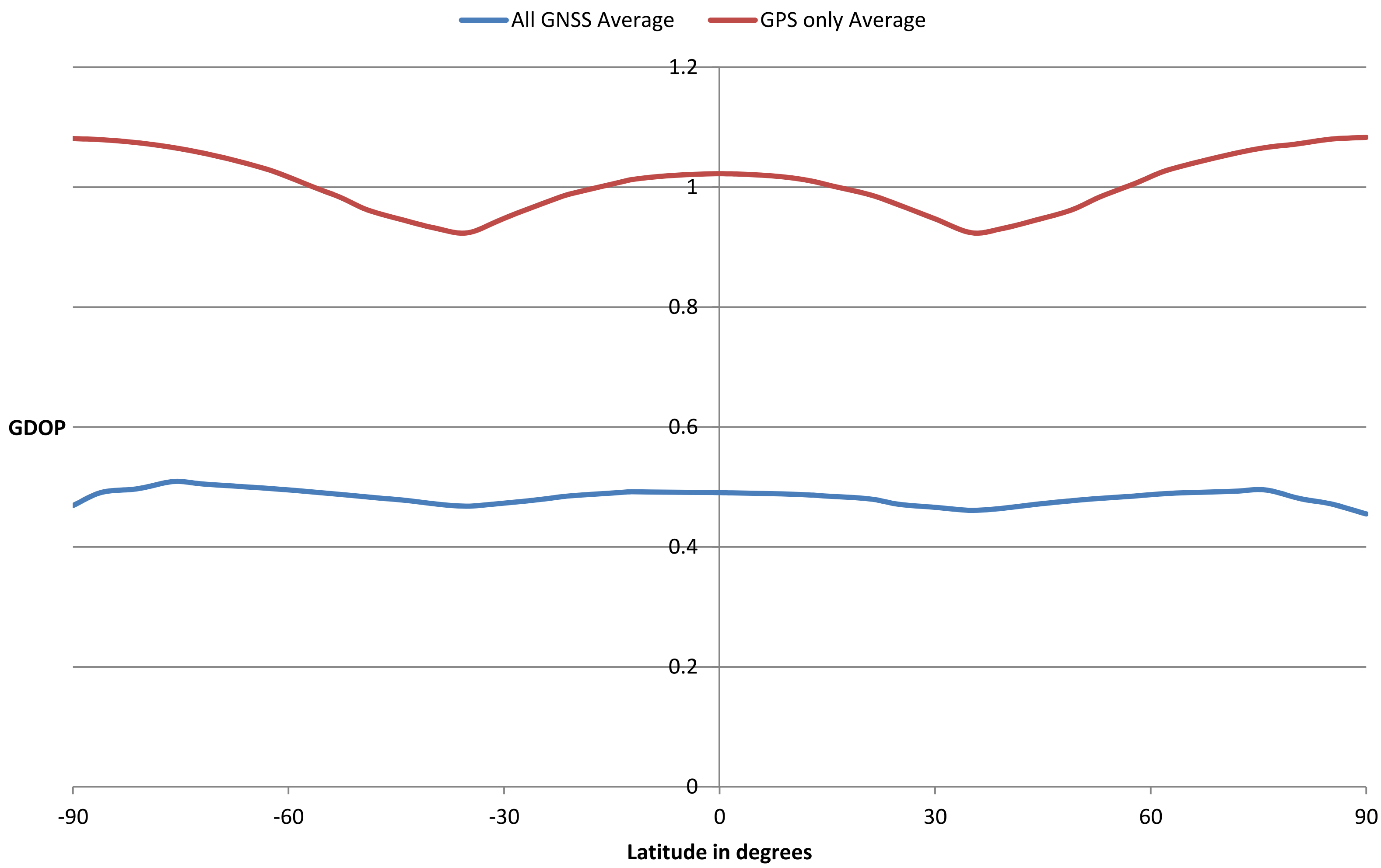
Assumed Constellations

- GPS: 24 + 3 configuration
- Galileo: 27 satellite configuration
- GLONASS: current 24 satellite configuration
- Beidou: 27 MEO, 5 GEO, 3 IGSO
- SBAS
  – WAAS: current 3 satellite configuration
  – EGNOS: current 3 satellite configuration
  – SDCM: planned 3 satellite configuration
  – QZSS: planned 3 satellite configuration
  – GAGAN: first satellite launched

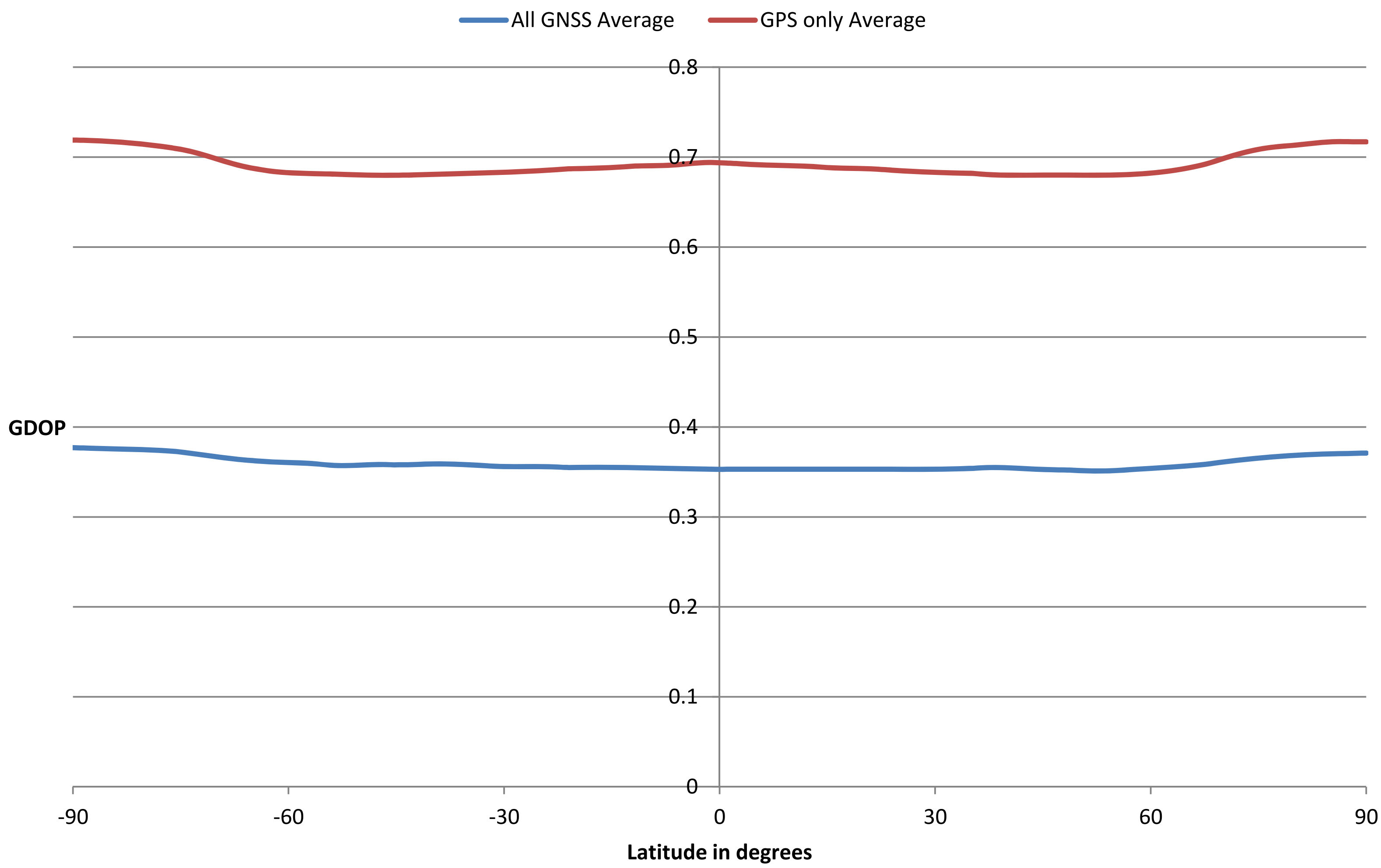
Coverage by 4 or more GNSS



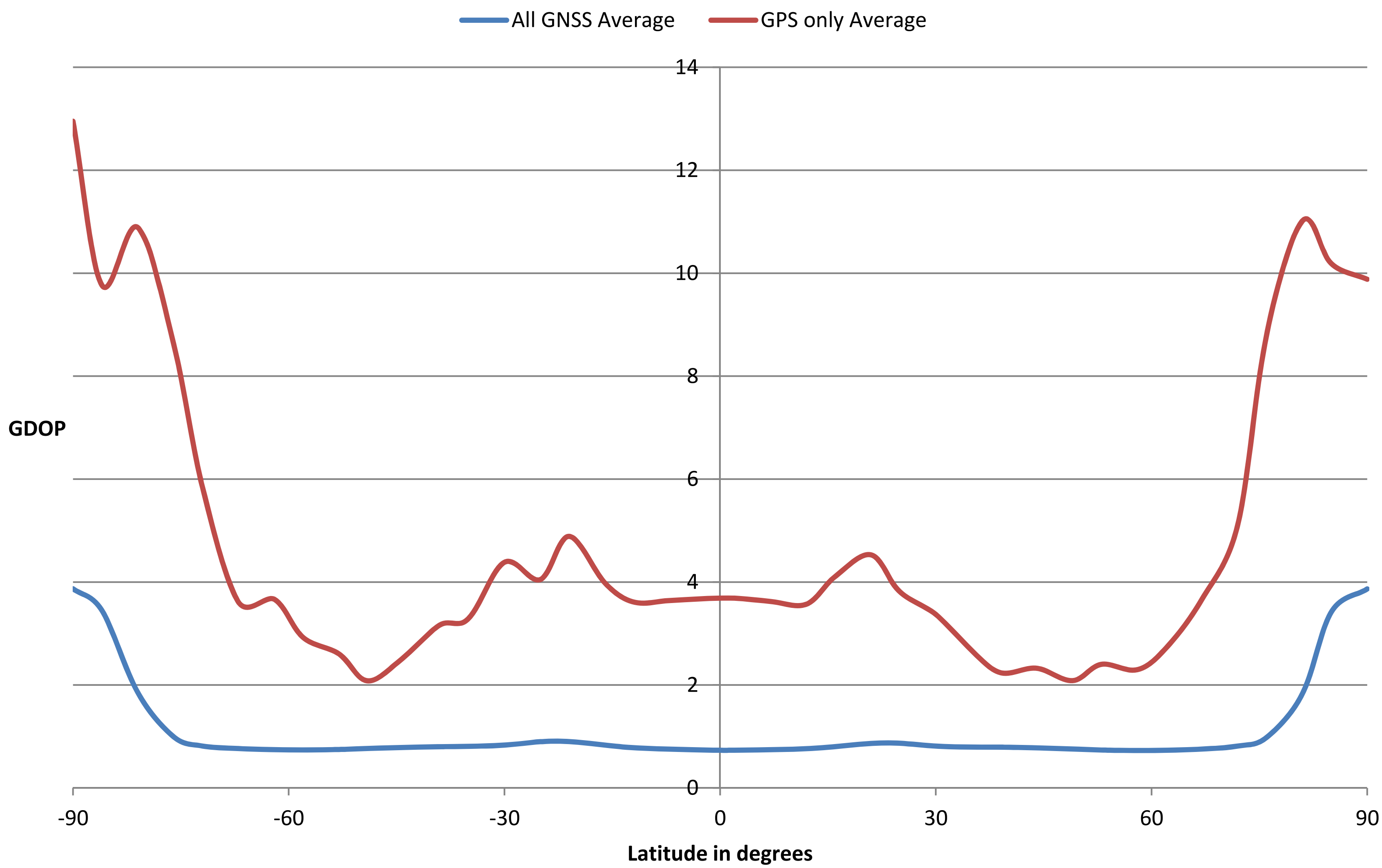
Geometric Dilution of Precision, 300 km



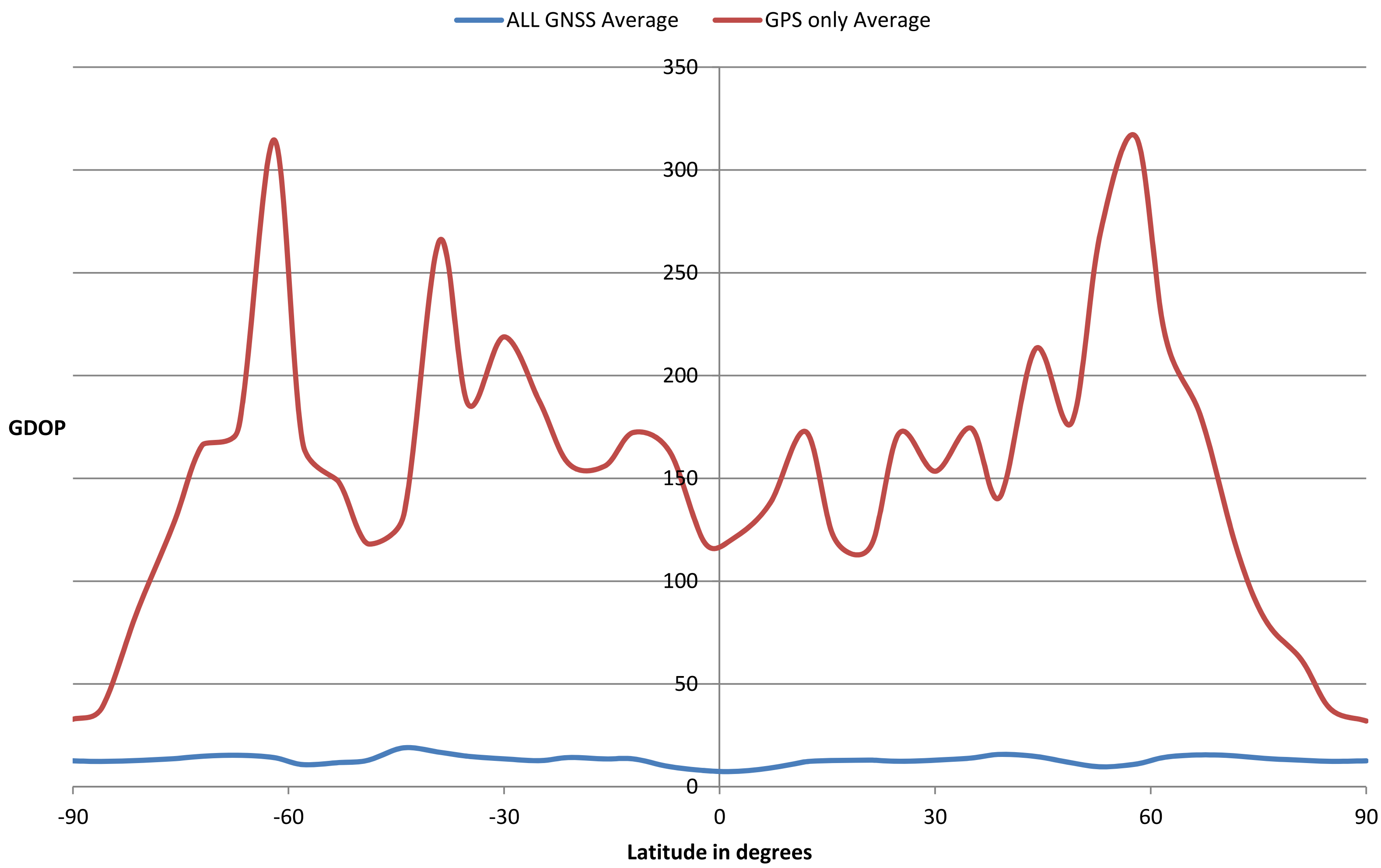
Geometric Dilution of Precision, 3000 km



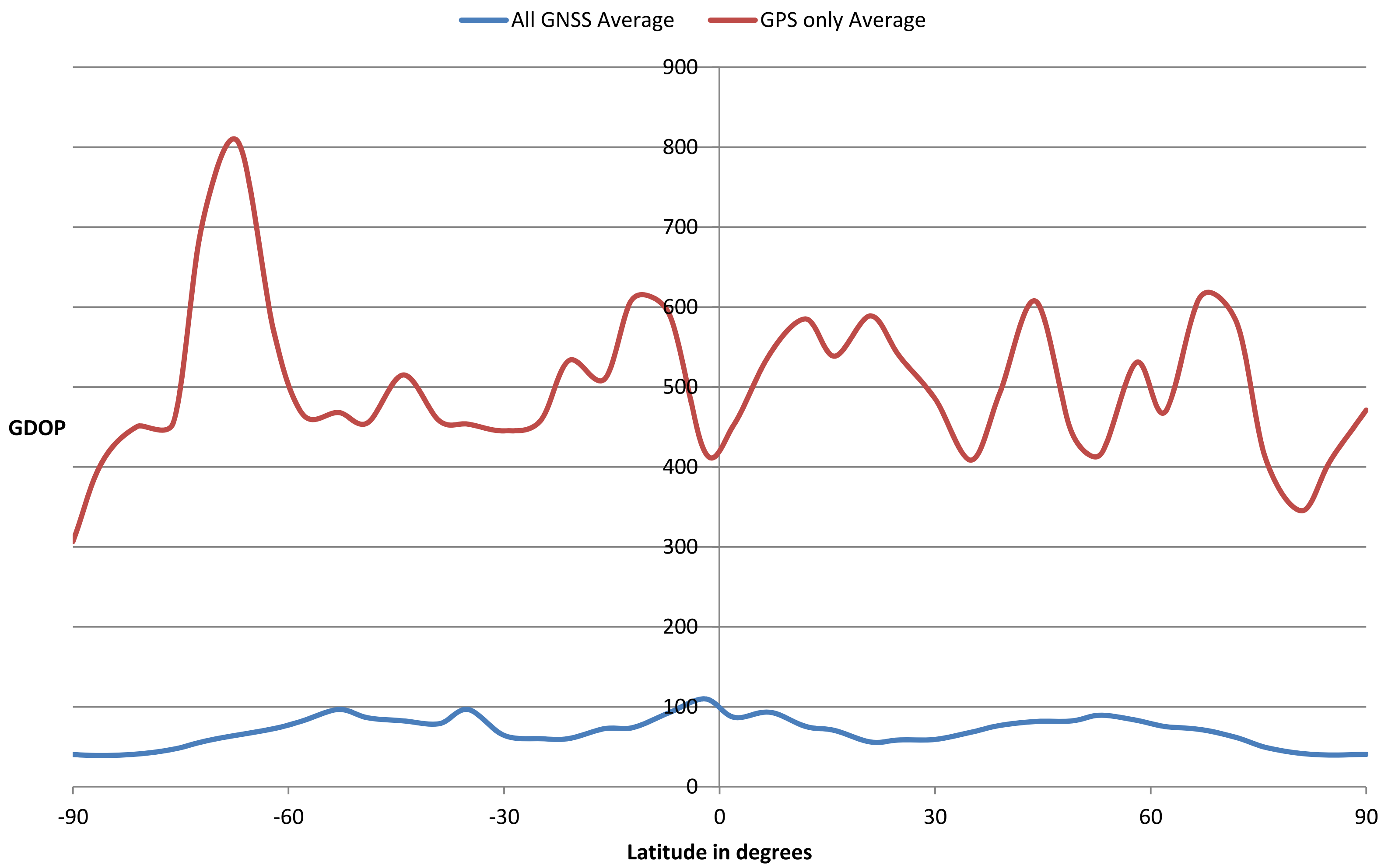
Geometric Dilution of Precision, 8000 km



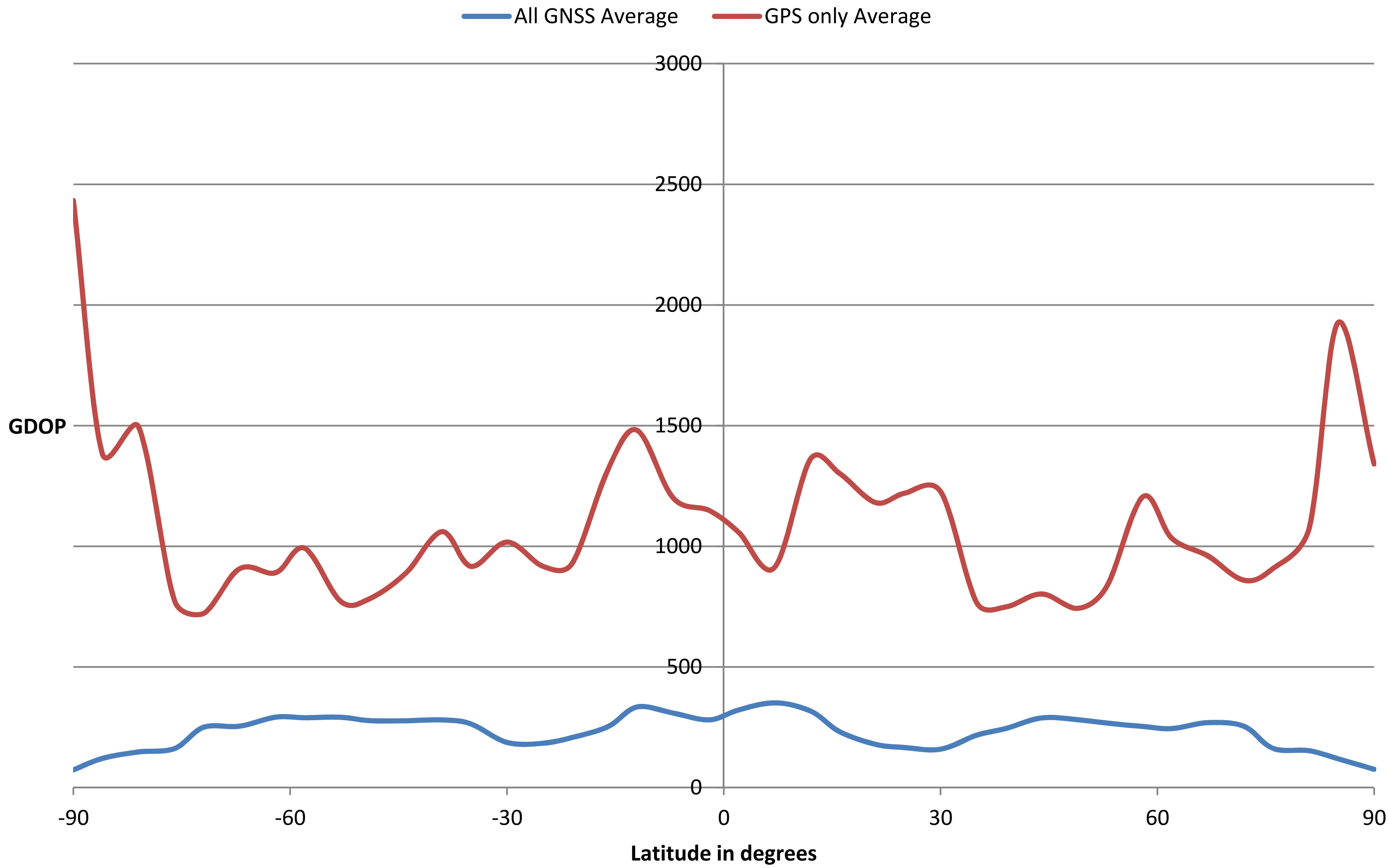
Geometric Dilution of Precision, 15000 km



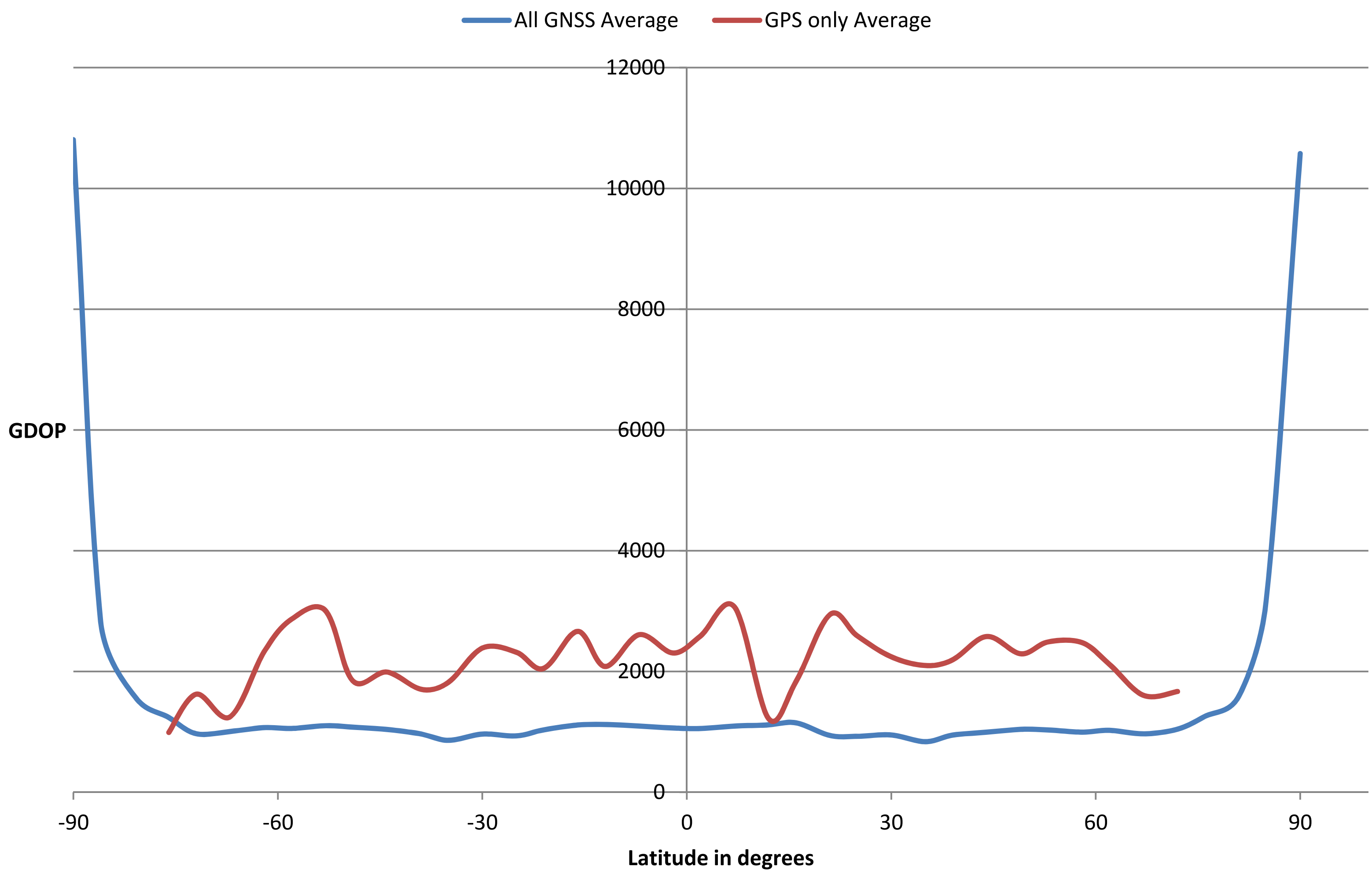
Geometric Dilution of Precision, 25000 km



Geometric Dilution of Precision, 36500 km



Geometric Dilution of Precision, 70000 km



Conclusions

- Typically, the use of multi-constellation GNSS navigation improves GDOP by a factor of two or more over GPS alone
- In addition, at the higher altitudes, four satellite solutions can be obtained much more often
- This show the value of having commitments to provide signals in the Space Service Volume

Follow-On

- Besides a commitment to provide a minimum signal in the Space Service Volume, detailed signal gain information is useful for mission planning
- Knowledge of group and phase delay over the pattern would also reduce the navigational uncertainty