

# **CONVERGENCE TIME IMPROVEMENT OF PRECISE POINT POSITIONING**

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# Outline

- Introduction
- Impact of Second-order Ionospheric Delay:
  - GPS Satellite Orbit
  - GPS Satellite Clock Corrections
  - PPP solution
- Conclusions and Future Outlook

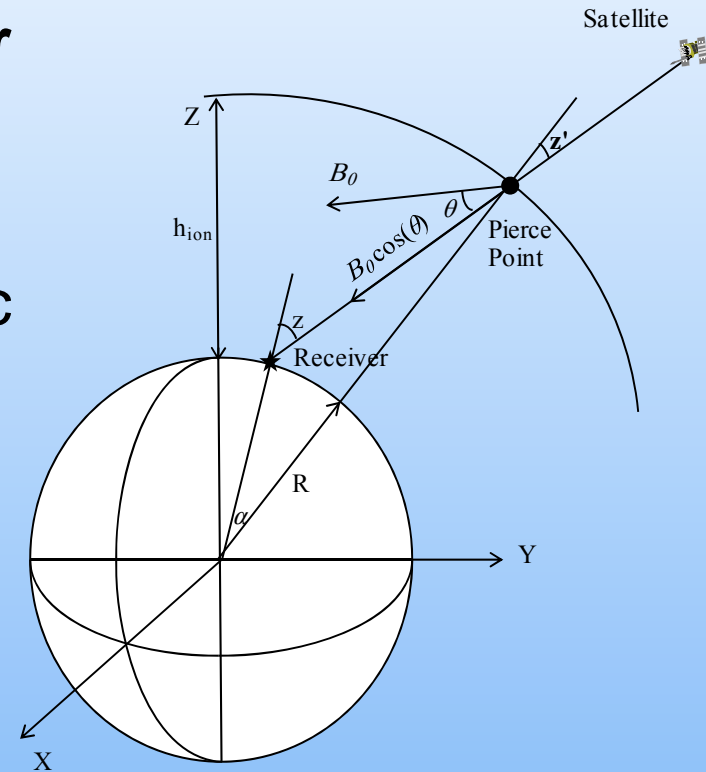
# Introduction

- Real-time and near real-time GPS precise point positioning (PPP) requires shorter convergence time for the estimated parameters
- Recent research has shown that not all errors and biases are rigorously modelled in PPP, which results in correlated residual errors
- Such unmodelled errors should be accounted for to achieve shorter convergence of the PPP solution
- Second-order ionospheric delays is considered one of the most important errors that should be considered in GPS PPP

# Second-order Ionospheric Delay

## ■ Factors Affecting Second-order Ionospheric Delay

- Total electron content
- Magnetic field at the ionospheric pierce point
  - Angle between magnetic field and propagation direction



# Second-order Ionospheric Delay (Cont'd)

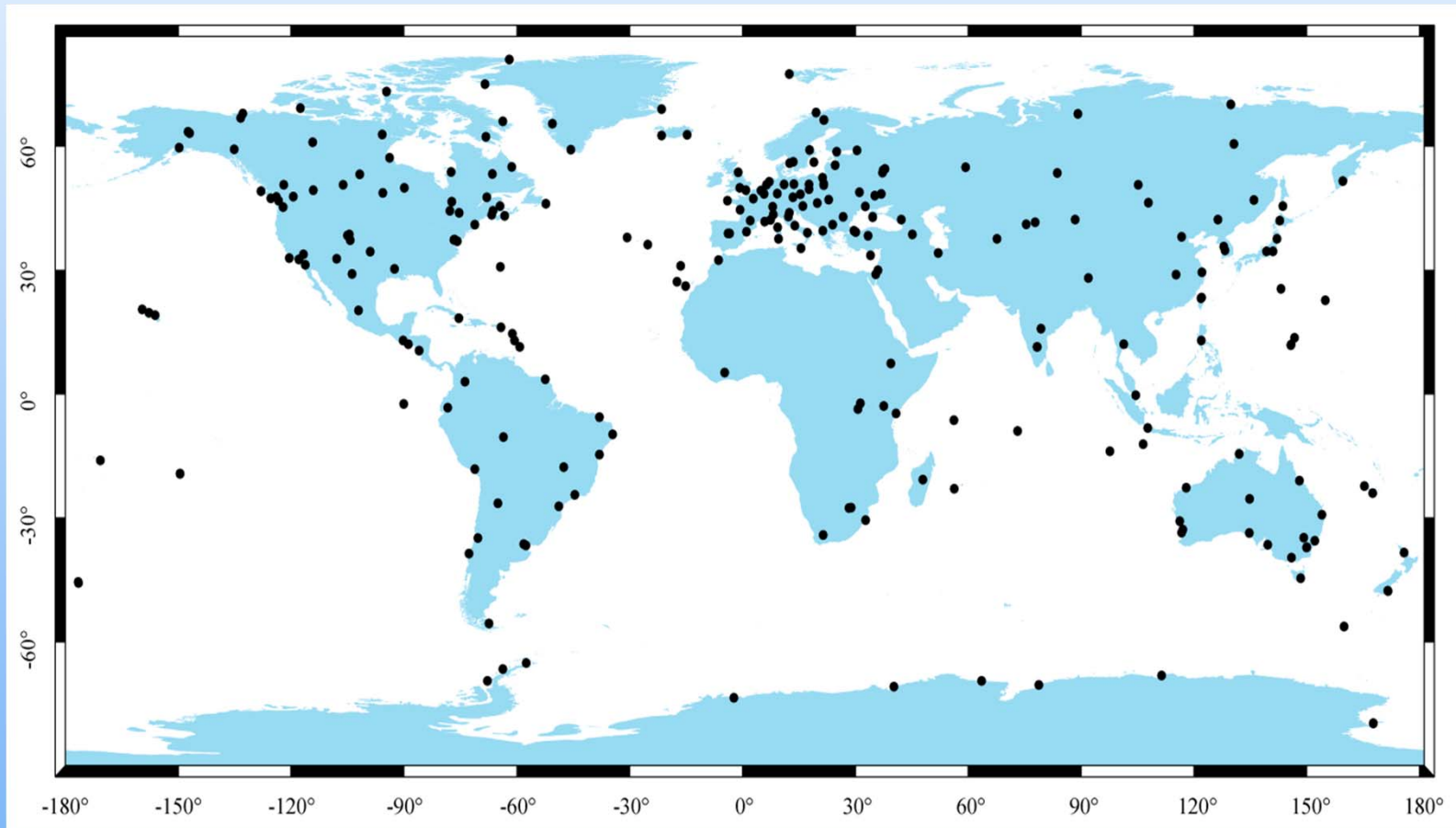
## Parameters of Geomagnetic Field

- Magnetic field parameters are estimated at the Ionospheric Pierce Point (IPP) using the 11<sup>th</sup> generation of International Geomagnetic Reference Field model (IGRF)

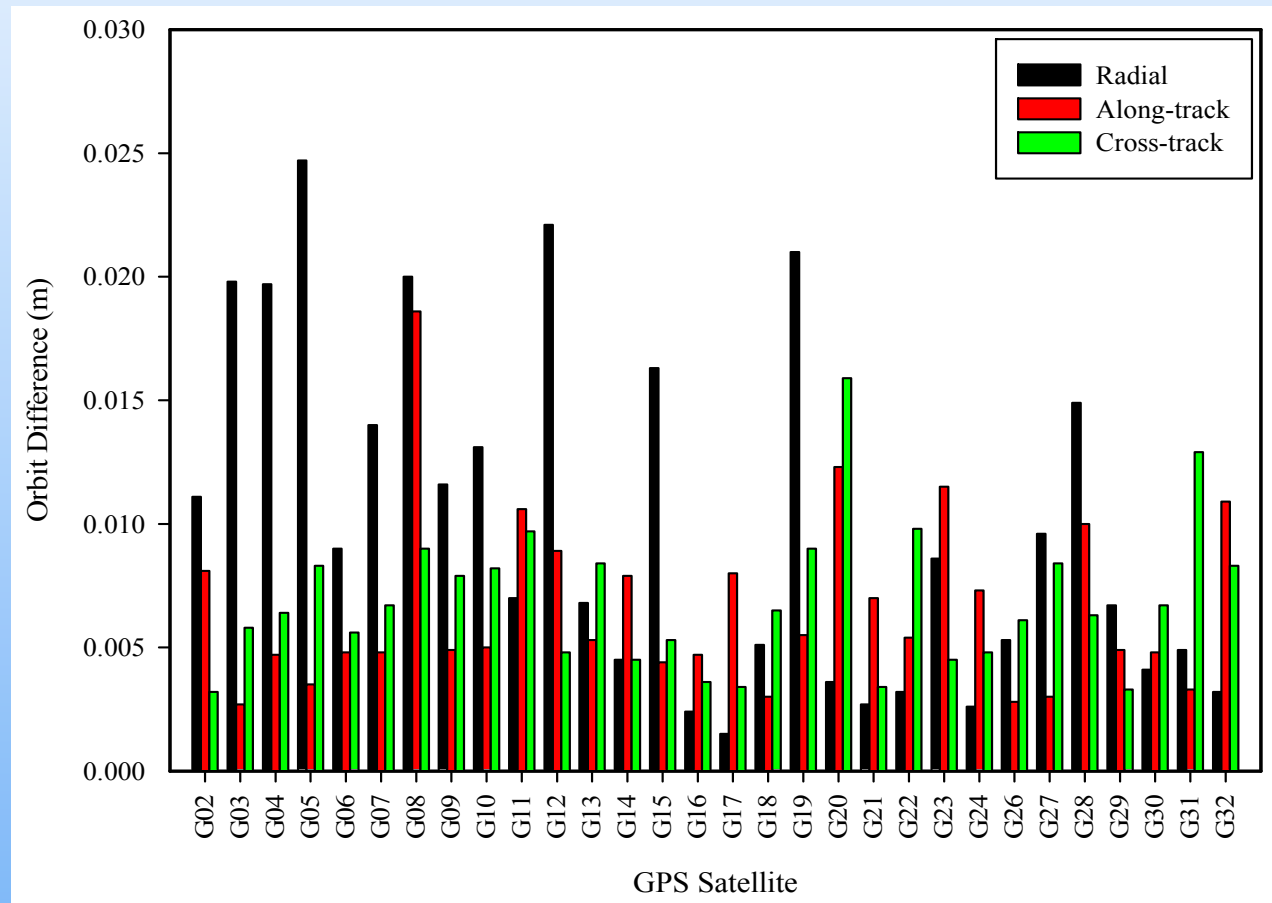
## Slant Total Electron Content (STEC)

- P1-P2 is used and satellites and receiver differential hardware delays are applied

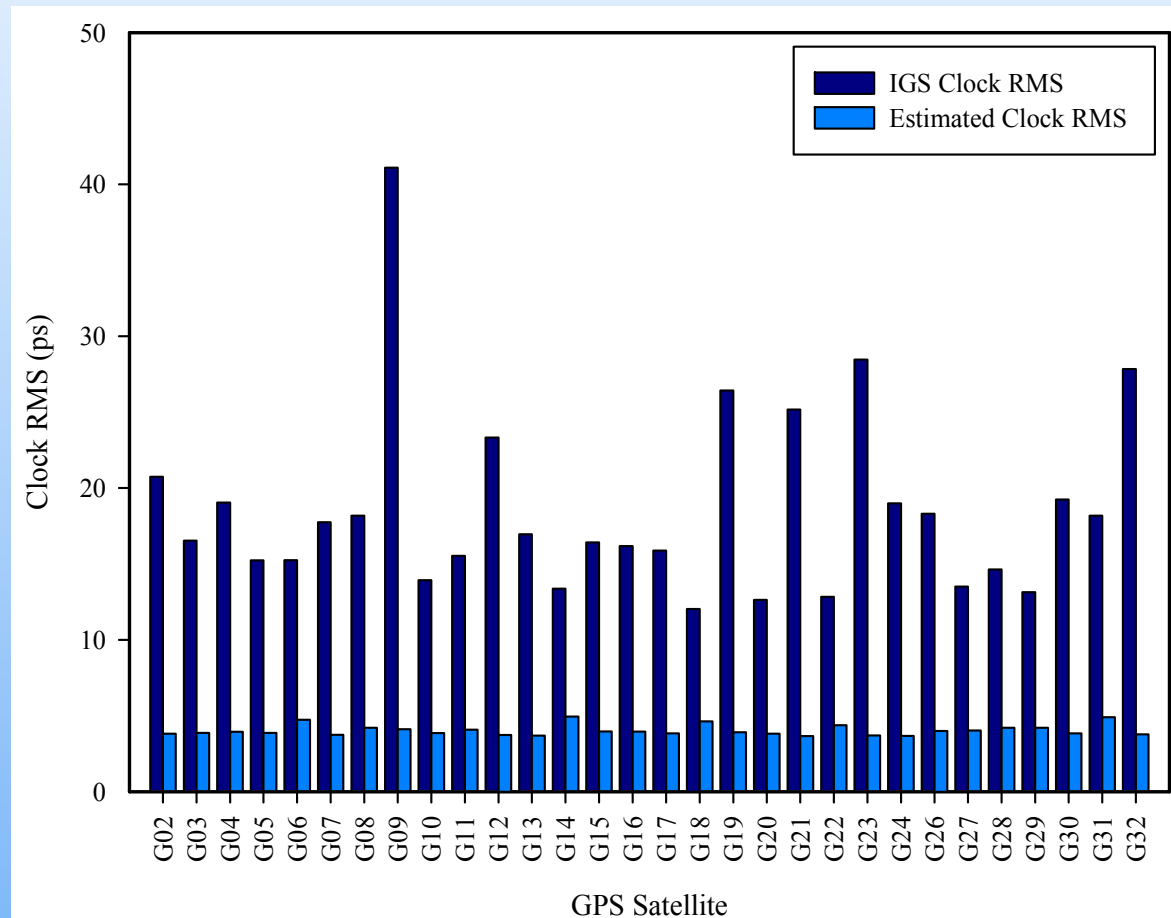
# IGS Stations Used in Estimating orbit and Clock Corrections



# Effect of Second-order Ionospheric Delay on Orbit Determination



# Effect of Second-order Ionospheric Delay on Clock Corrections

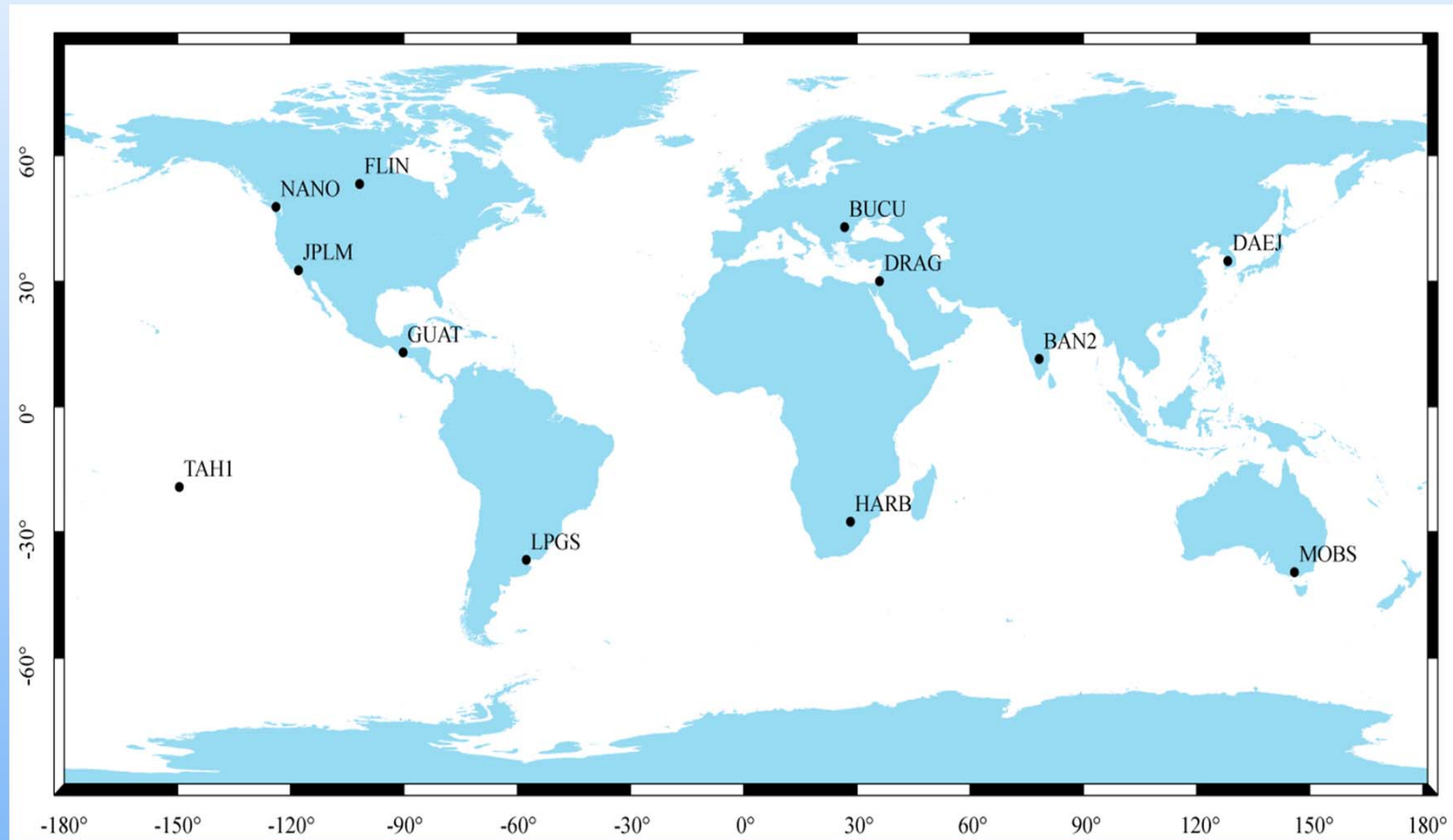




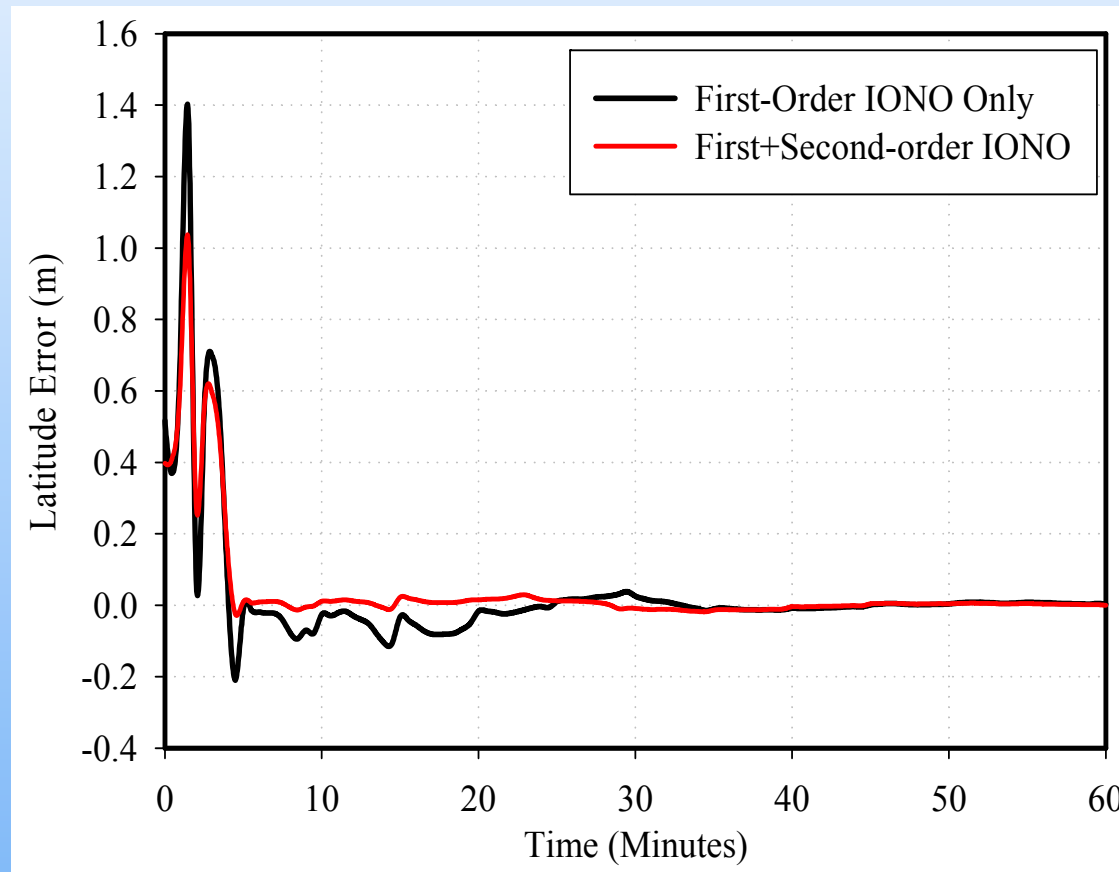
# Effect of Second-order Ionospheric Delay on PPP Solution

- NRCan GPS PPP software is modified to accept the second-order ionospheric delay correction
- The estimated satellite orbit and clock corrections are used to process the GPS data of several GPS stations
- First-order ionosphere-free linear combination of both code and carrier-phase are used and the correction for the second-order ionospheric delay is applied for both observables

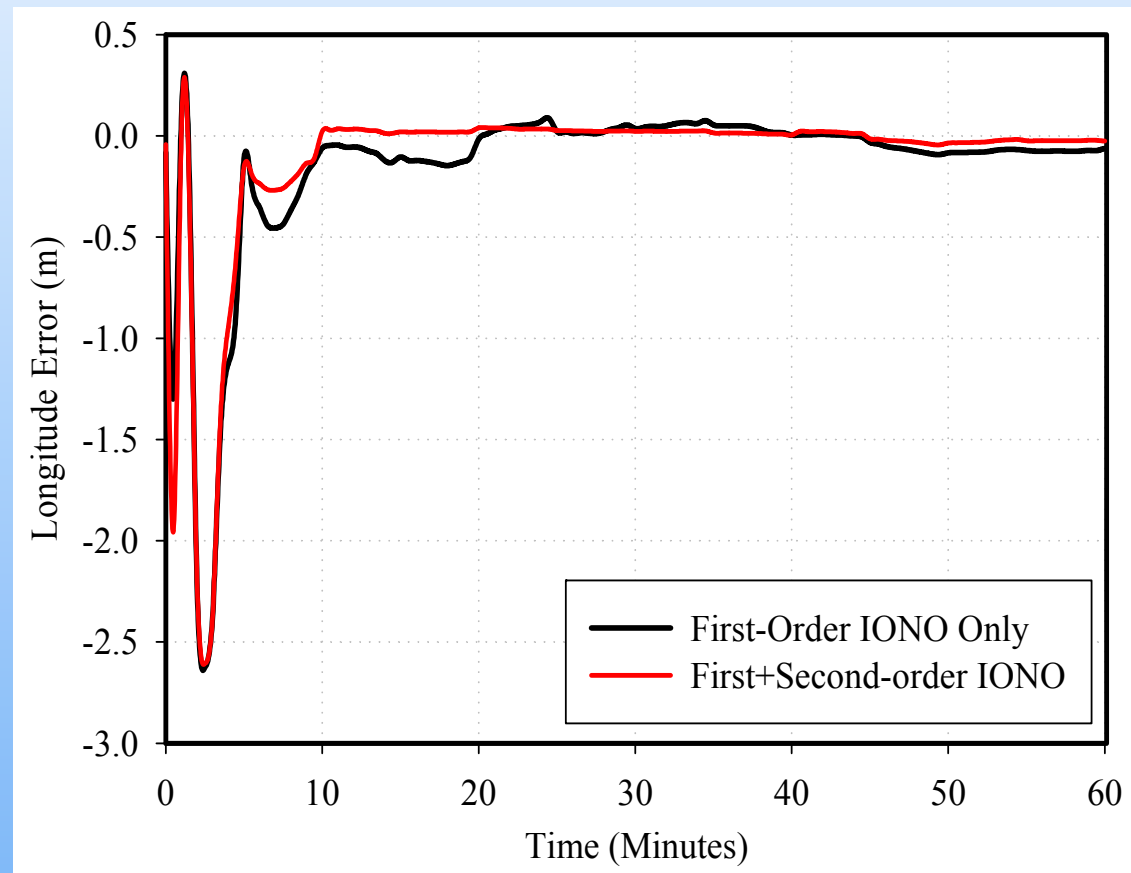
# IGS Stations Used to Verify the Estimated Orbit and Clock Corrections



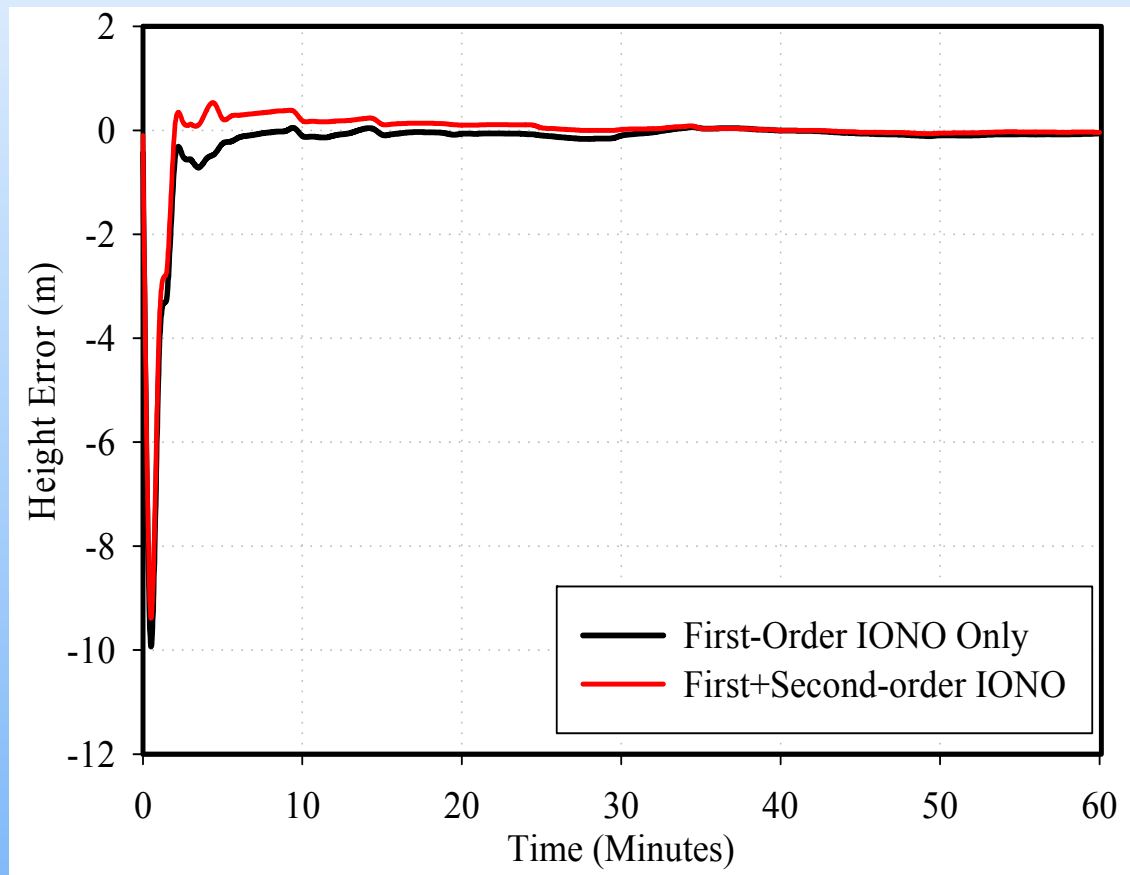
# Latitude Results for Station DRAG – DOY125, 2010



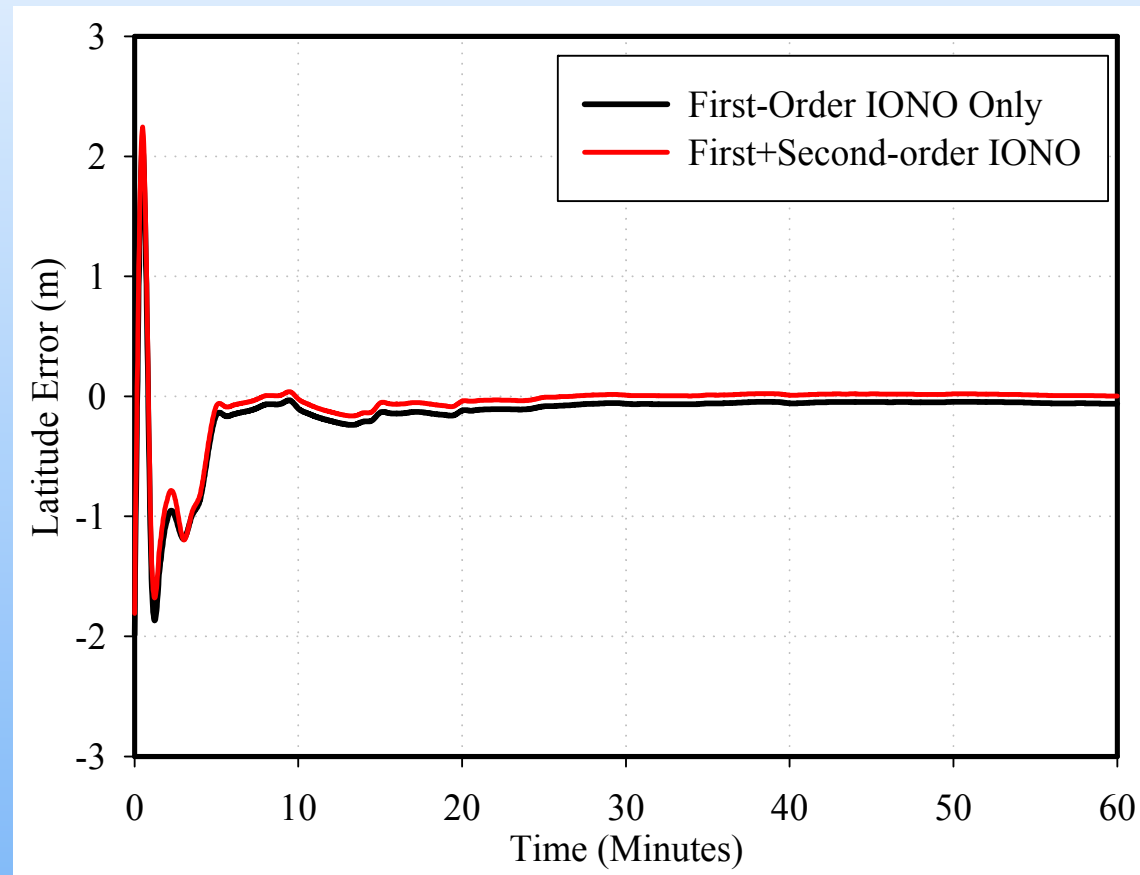
# Longitude Results for Station DRAG – DOY125, 2010



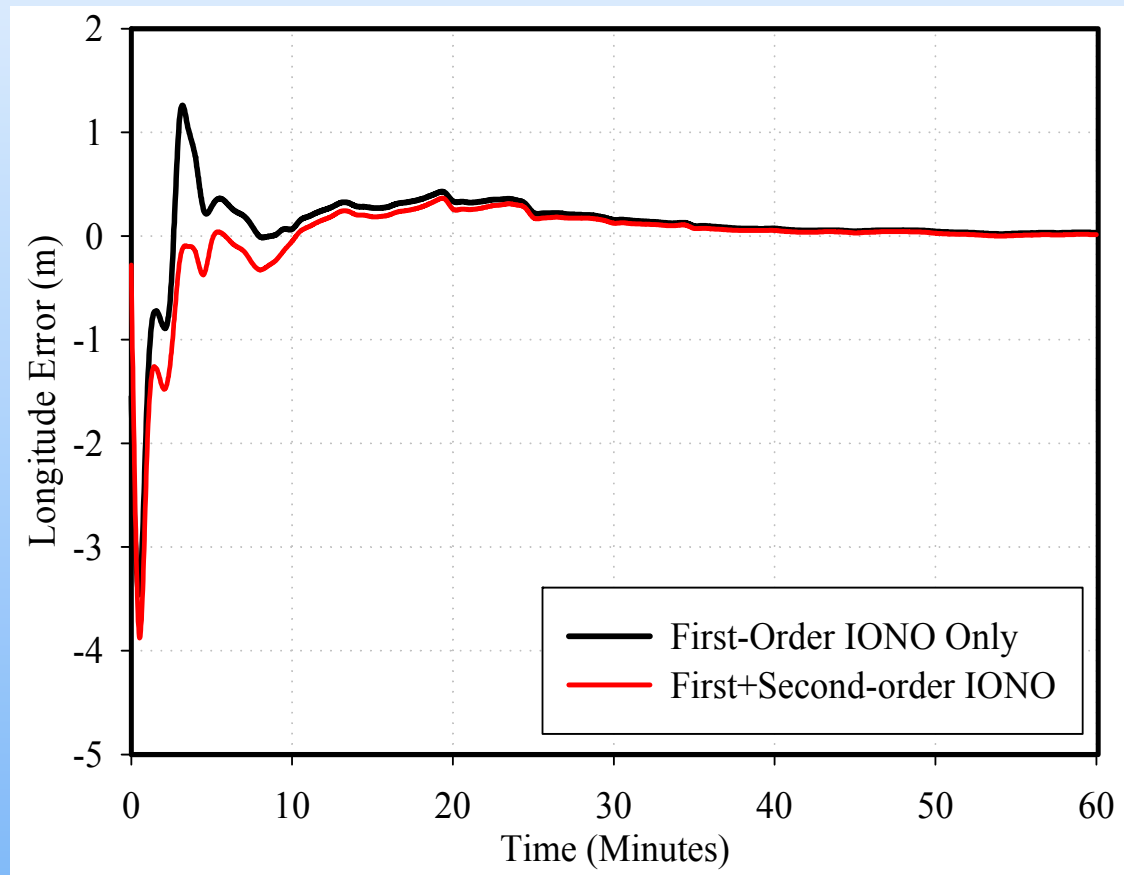
# Height Results for Station DRAG – DOY125, 2010



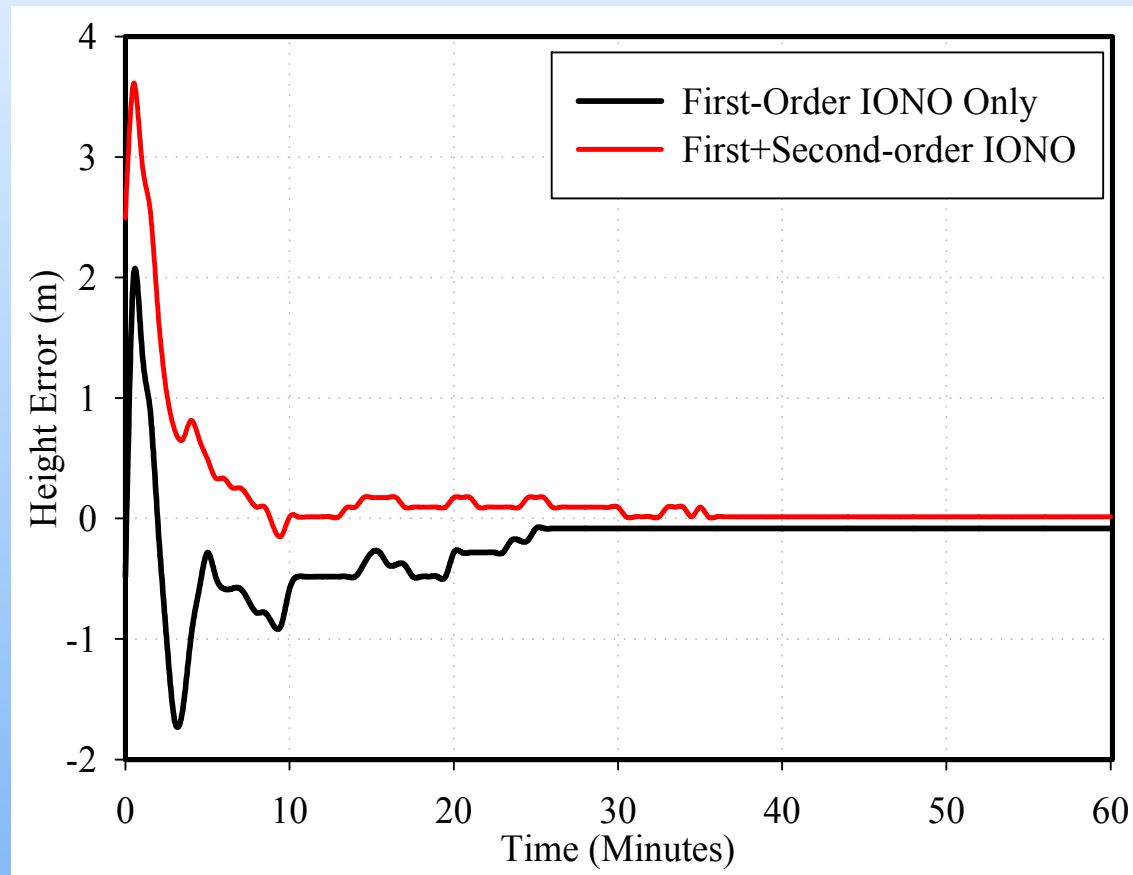
# Latitude Results for Station THA1 – DOY125, 2010



# Longitude Results for Station THA1 – DOY125, 2010



# Height Results for Station THA1 – DOY125, 2010





# Conclusions and Future Outlook

- The impact of the second-order ionospheric delay on GPS satellite orbit and clock corrections is investigated
- The results showed that an error in the GPS satellites orbits ranges from 1.5 to 24.7 mm in radial, 2.7 to 18.6 mm in along-track, and 3.2 to 15.9 mm in cross-track directions, respectively
- Second-order ionospheric-delay can cause satellite clock error up to 0.067 ns (2 cm)

# Conclusions and Future Outlook (Cont'd)

- Accounting for the second-order ionospheric delay can improve the PPP coordinate solution by about 3 mm and the convergence time by about 15%
- Future research will develop between-satellite single-difference (BSSD) algorithm
- BSSD PPP with accounting for the second-order ionospheric delay will be the key for carrier-phase ambiguity resolution in PPP



**Thank You!**