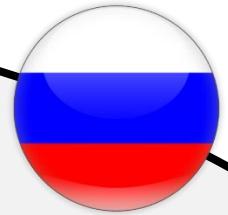
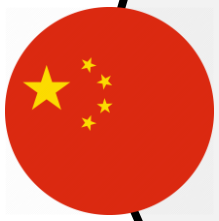
CSIR-4PI



Analysis of multi-GNSS data of continuous sites in Indian subcontinent



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Outline

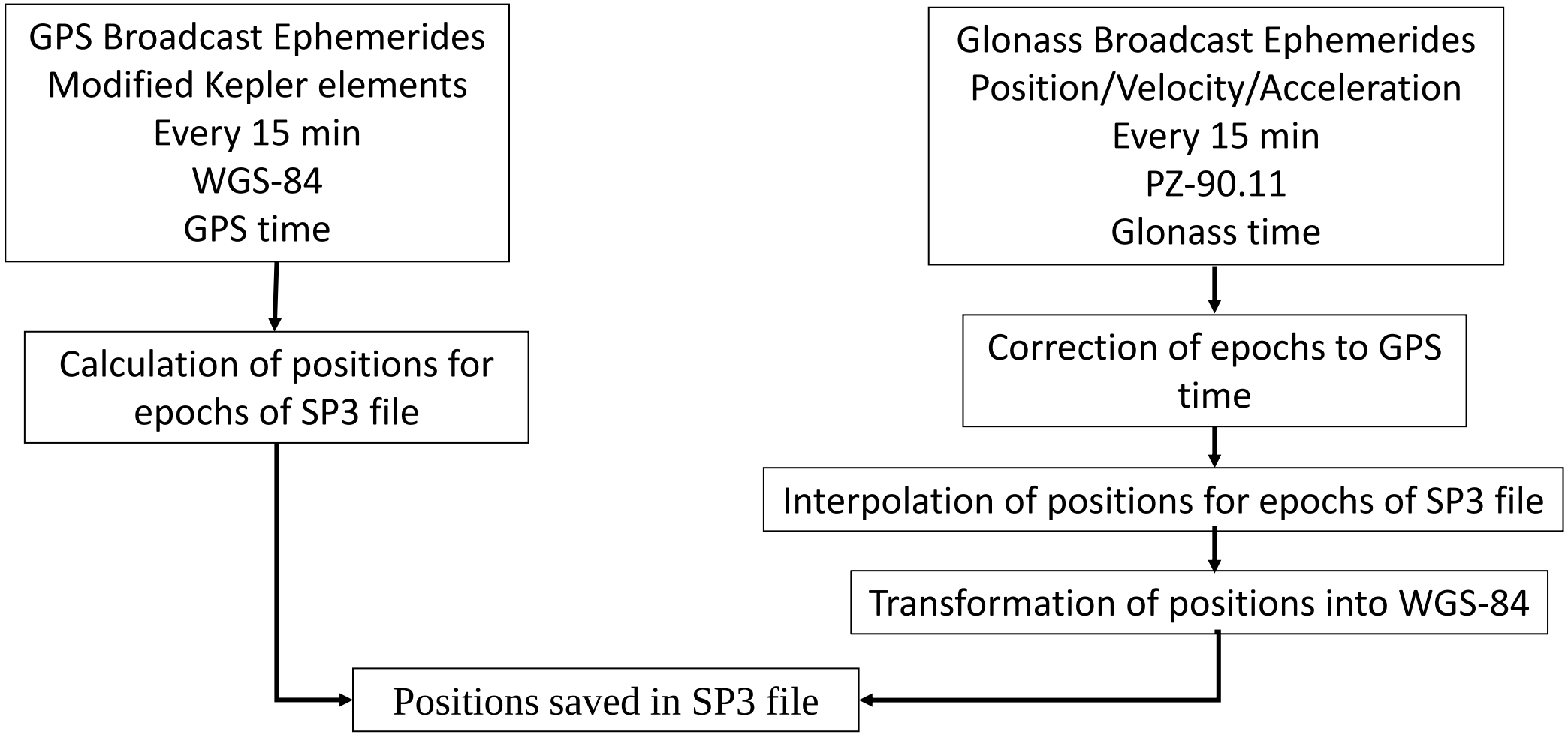
- Introduction
- Multi-GNSS data analysis
- Pilot study
- Position, velocity & noise estimates
- Conclusion & future work

Introduction

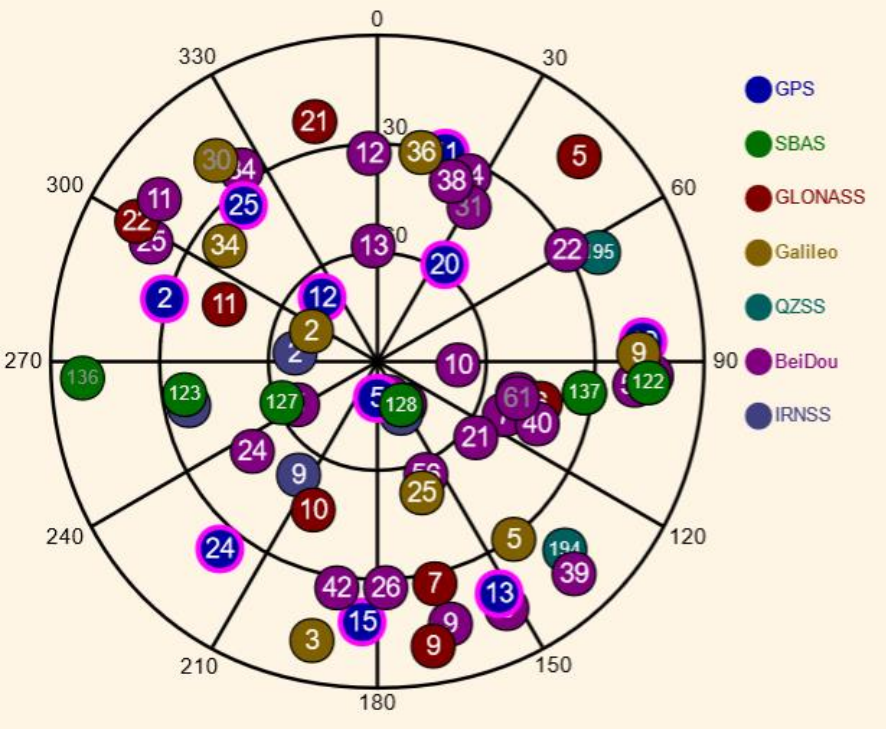
- Positions and velocities are estimated using standalone GPS (GPS), standalone Glonass (GLO) and combined GPS-Glonass (GGL) data of continuous mode GNSS stations in Indian subcontinent for the first time.
- To combine different constellations data, it is required to have

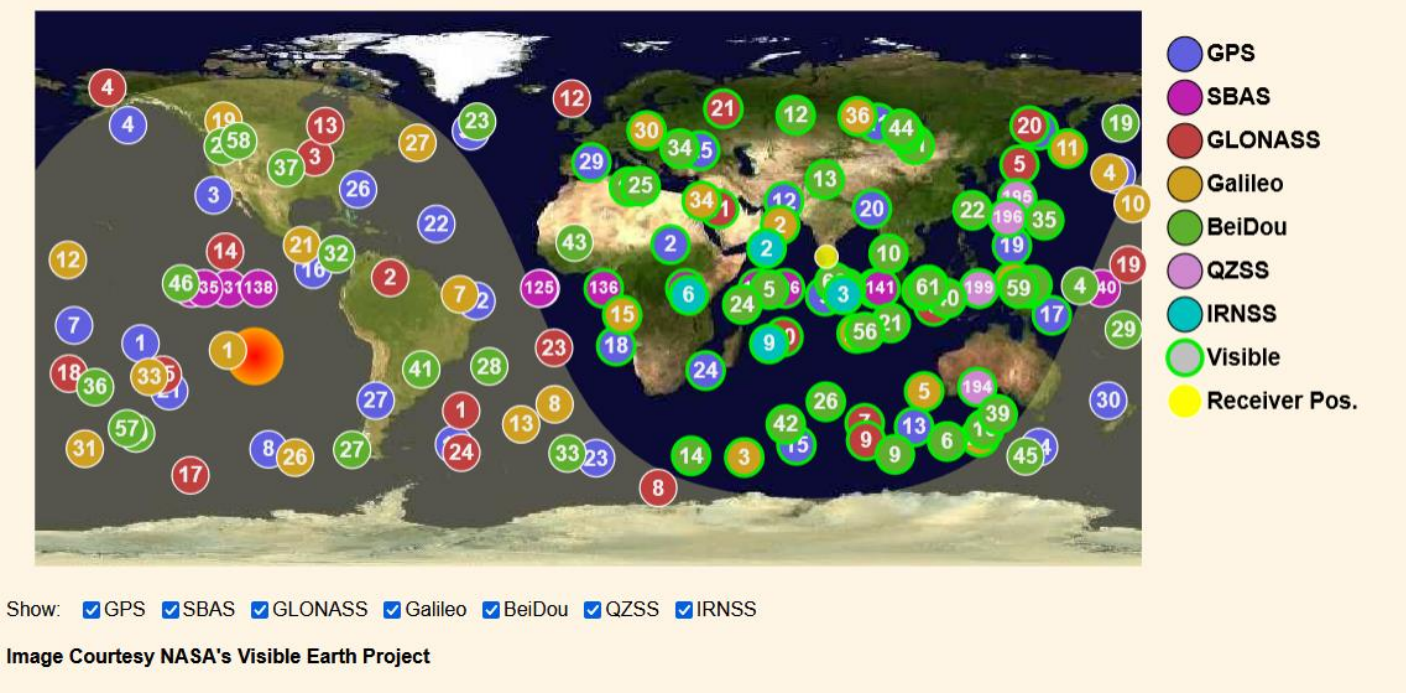
1) Unique reference system
2) Unique time scale
3) Combined satellite ephemerides

Combined GPS/Glonass orbit generation



Satellites tracked by CSIR-4PI cGNSS station





Skyplot & constellation status of Trimble Alloy receiver

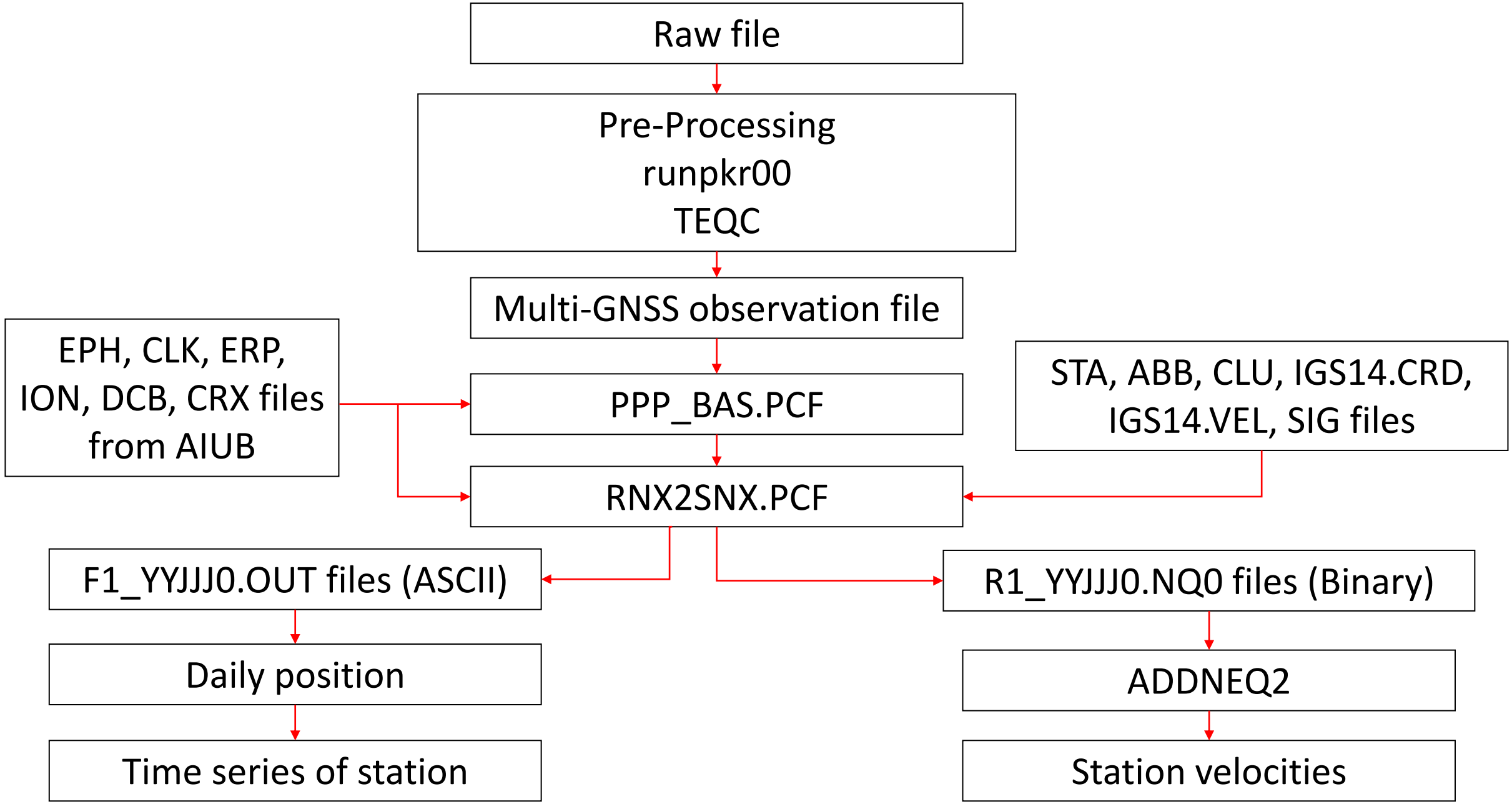
Multi-GNSS softwares

- GAMIT/GLOBK release 10.71 developed by MIT, Scripps Institution of Oceanography and Harvard University with support from the National Science Foundation can process GPS, Glonass, Galileo, BeiDou data individually.
- GipsyX software is developed by the Jet Propulsion Laboratory (JPL) and can process GPS, Glonass data individually.
- Bernese software version 5.4 is developed by Astronomical Institute University of Bern (AIUB) which supports individual and combined multi-GNSS (GPS, Glonass, Galileo, BeiDou & QZSS) data processing.

Multi-GNSS Data analysis

- To study the impact of multi-GNSS data on position and velocity esimates, a pilot study is carried out using Bernese software version 5.2 and results are discussed in subsequent section.
- 17 cGNSS stations in Indian sub-continent along with 13 only multi-GNSS IGS stations is processed and analyzed for further studies.
- 6 years (2015 to 2021) of data is used to calculate the position, velocity and noise estimates.
- Bernese Processing Engine (BPE) is used for automated data processing.

Flowchart of Multi-GNSS data processing

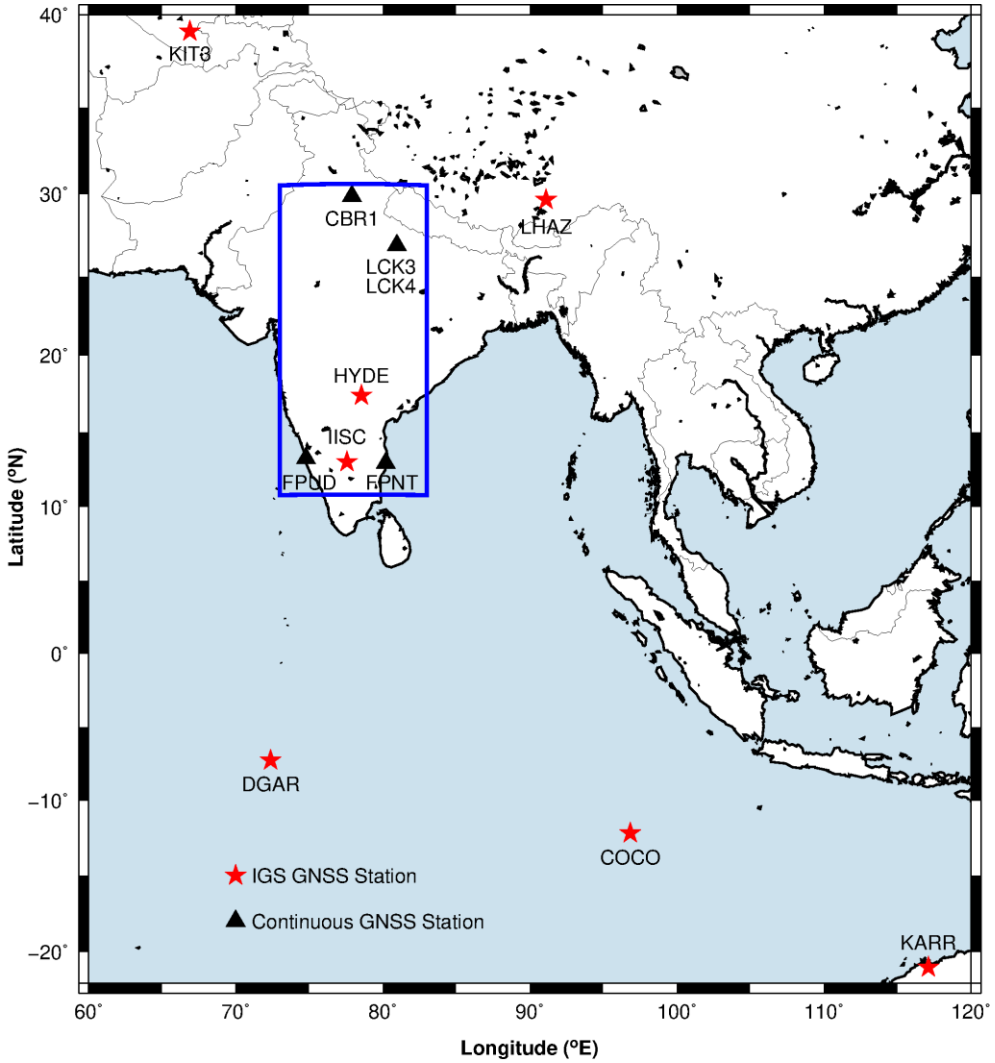


Pilot study*

- Data of 5 cGNSS stations and 7 IGS multi-GNSS stations is processed and analysed to

1. Compare 60 days of GNSS daily position estimates.
2. Compare multi-year velocity estimates using 7 epochs of cGNSS data (each of 10 days duration) from 2016 to 2019.

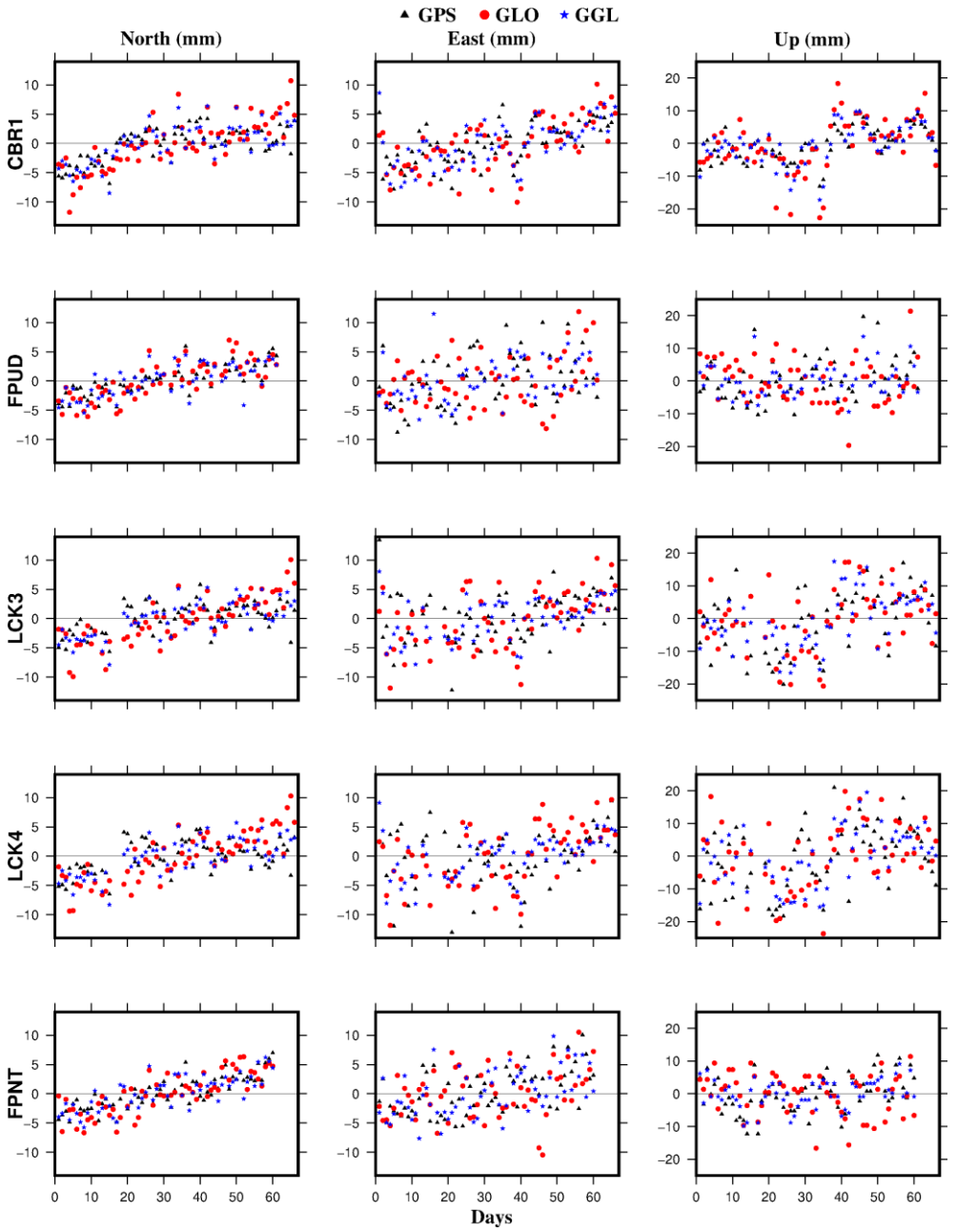
**Vivek et. al 2020*



cGNSS sites of India along with IGS Multi-GNSS stations

Daily position time series

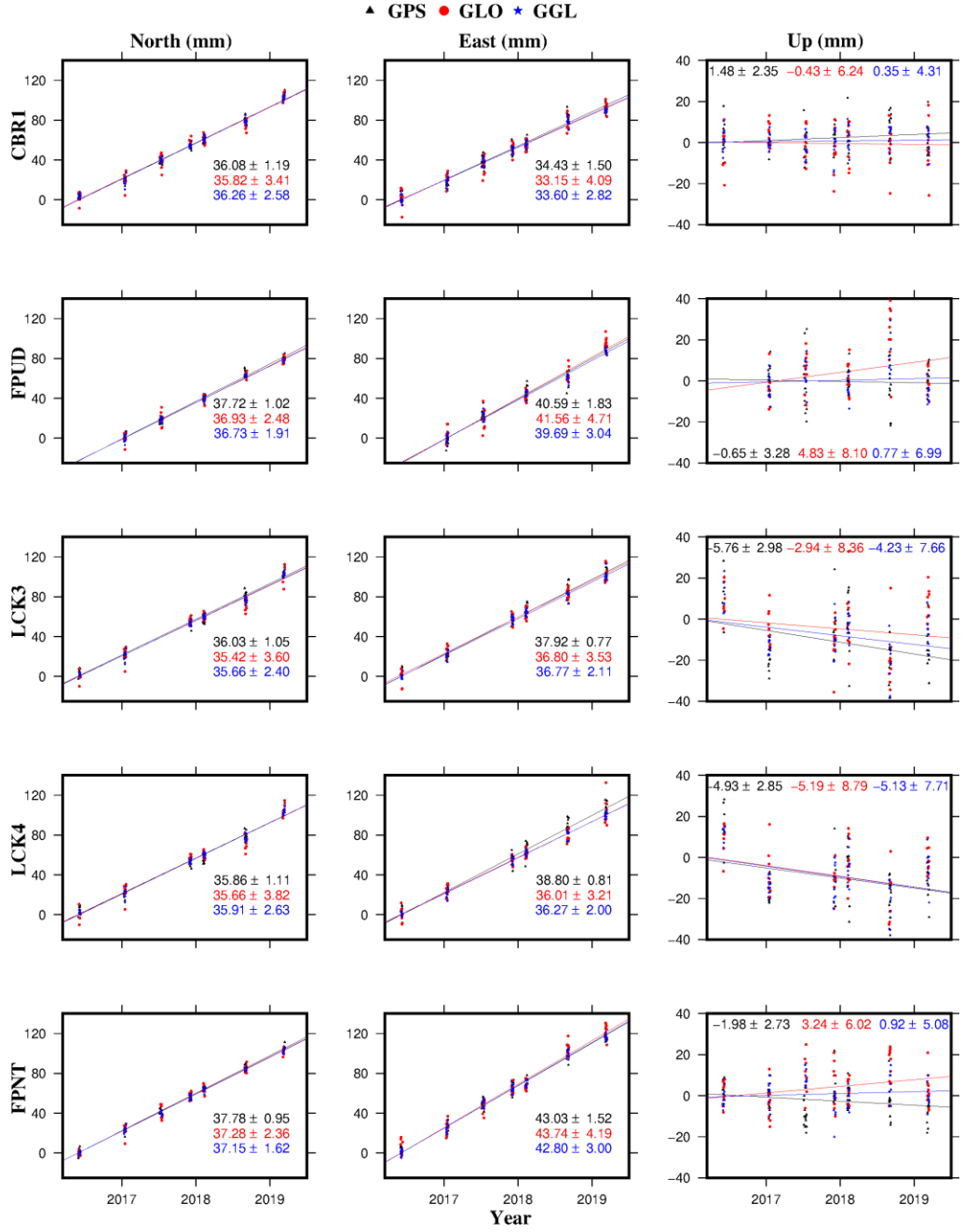
- Scatter is high in GLO time series compared to GPS and GGL time series due to the receiver clock bias term in Glonass solution.
- Scatter is high in East component compared to North component for all the three solutions (GPS, GLO, GGL). Reason is East component could not be constrained well due to the limited IGS multi-GNSS stations and only two stations are located in India along the North-South line of stations.



Daily position time series in North, East, and Up components using GPS, GLO and GGL of cGNSS sites

Multi-year time series

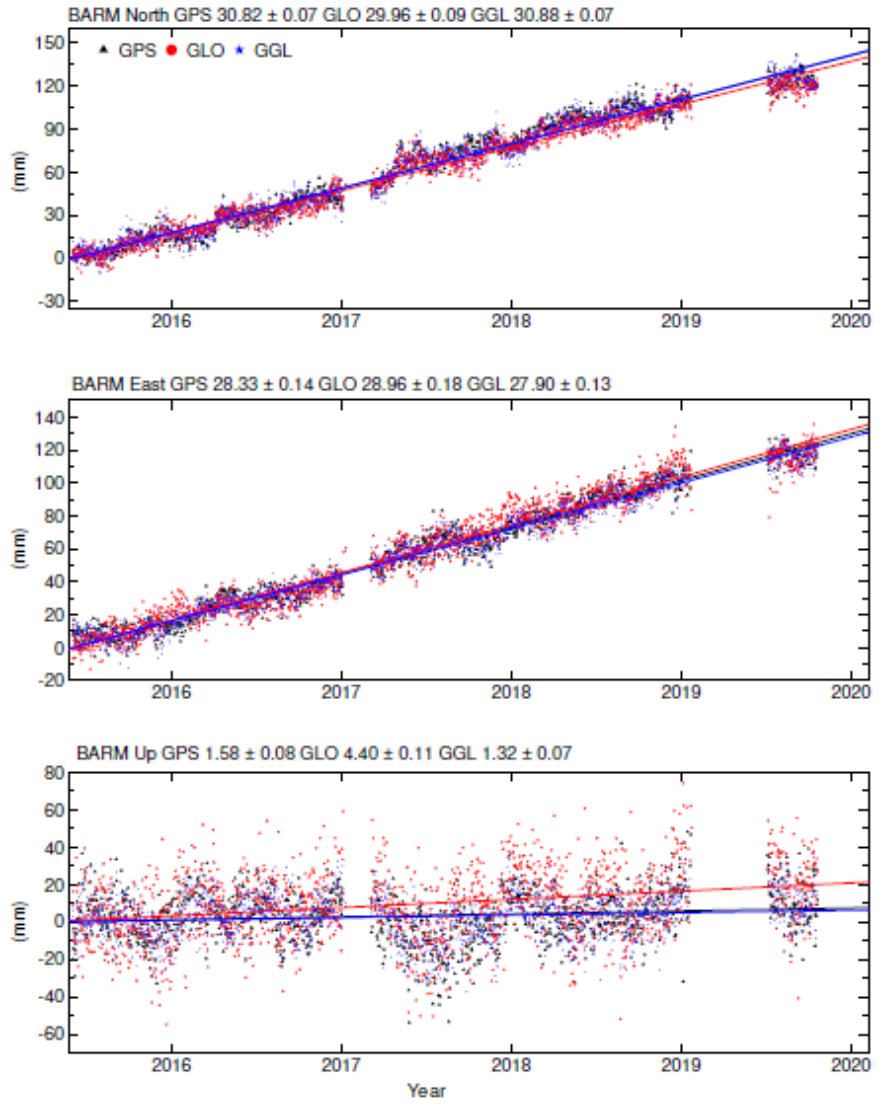
- North component of velocity for all the sites differs by ±1 mm well within the NRMS error value for all the solutions.
- Large difference (1-3 mm) is observed in the East component for all the solutions due to insufficient spatial spread of IGS stations with multi-GNSS data.
- GGL solution show very little improvement compared to only GPS solutions for both positon and velocity estimates.



Multi-year time series of North, East, and Up components for GPS, GLO and GGL solutions of cGNSS sites.

Position and Velocity estimates

- In position estimates of long time series, scatter is high for GLO compared to GPS and GGL.
- Estimated individual and combination station velocities using GLO and GGL are within 1 to 3 mm range of GPS for both North and East components.



GPS, GLO, GGL time series of station

Noise estimates

- Noise estimates for the stand-alone GPS, Glonass and combined GPS-Glonass time series are calculated using CATS software.

Error sources in GNSS time series

- Unmodelled motions of the station
  - Monument instability
  - Loading of the crust by atmosphere, oceans and surface water
- Signal propagation effects
  - Receiver noise--Negligible
  - Ionospheric effect--Removed in Dual frequency receivers
  - Signal scattering (Multipath)
  - Atmospheric delay (Water vapor)
- Unmodelled motions of the satellites—Negligible

Source: UNAVCO GAMIT/GLOBK course, July, 2022

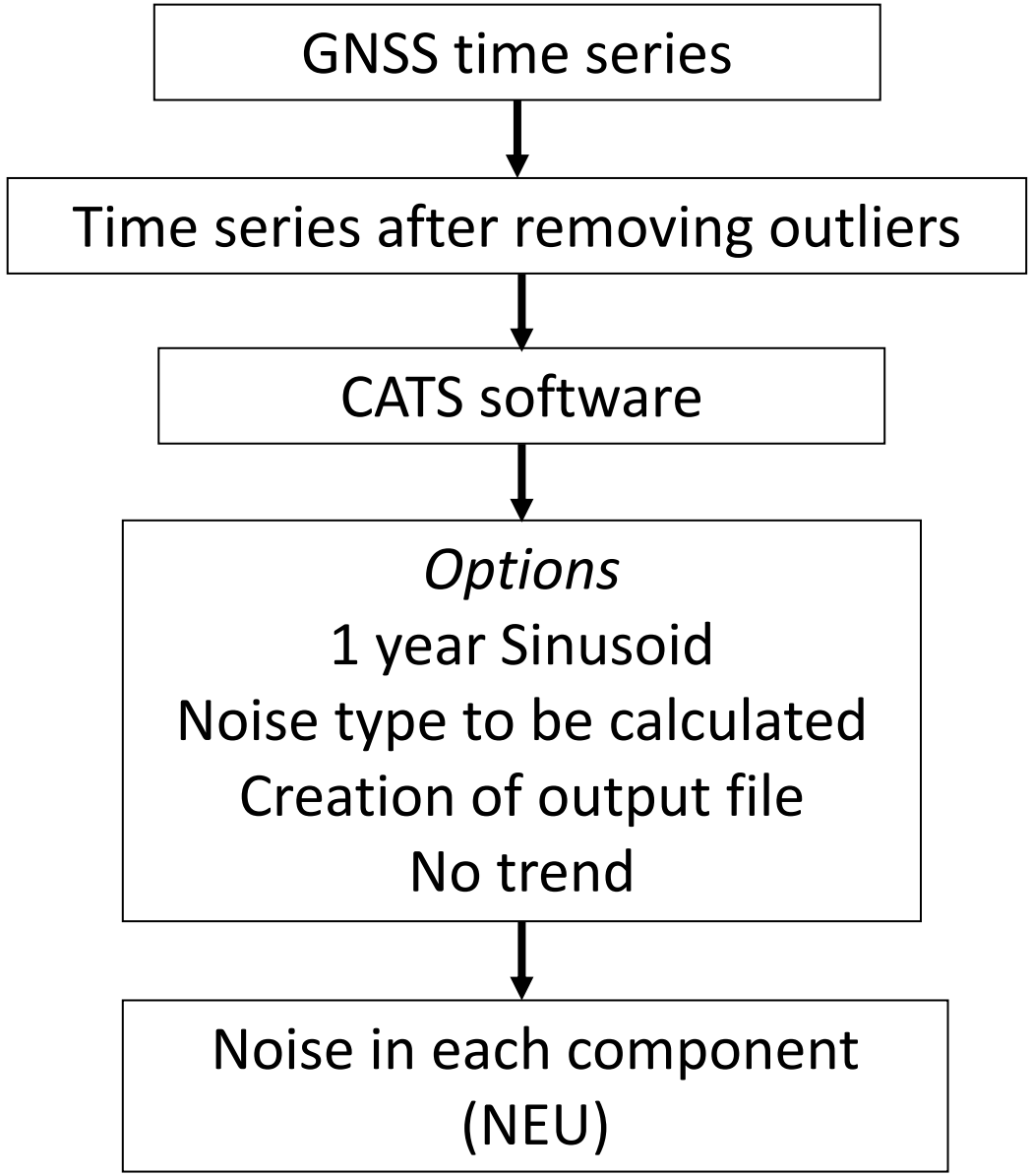
Types of Noise

- Velocity uncertainties are determined mainly by the noise levels in position estimates and length of the time series.
- Mainly time series consists of noise uncorrelated in time (White noise) and temporally correlated noise (Mao et al. 1999).
- White noise affects can be significantly reduced by using repeated/more measurements (K. Dmitrieva et al. 2015).
- Time-dependent noise influence is more for the long time series (Langbein 2012).

CATS software

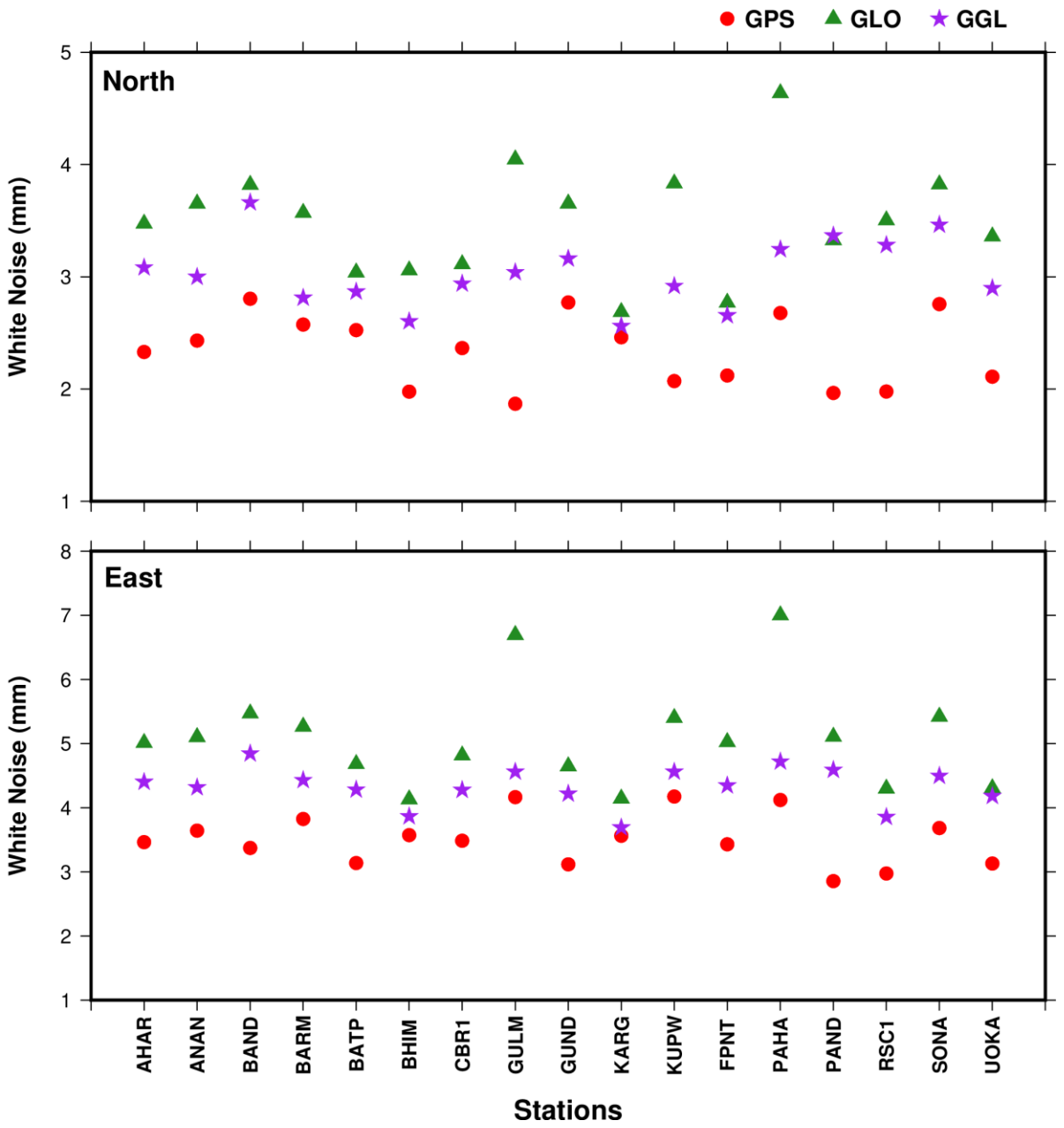
- CATS (Create and Analyze Time Series) sofwtare is used for noise estimation.
- Stand-alone C program to calculate the noise in GNSS time series.
- Command line based software which needs each direction time series.
- Software can trend the time series, if there are any data gaps.

Flow chart of CATS software processing



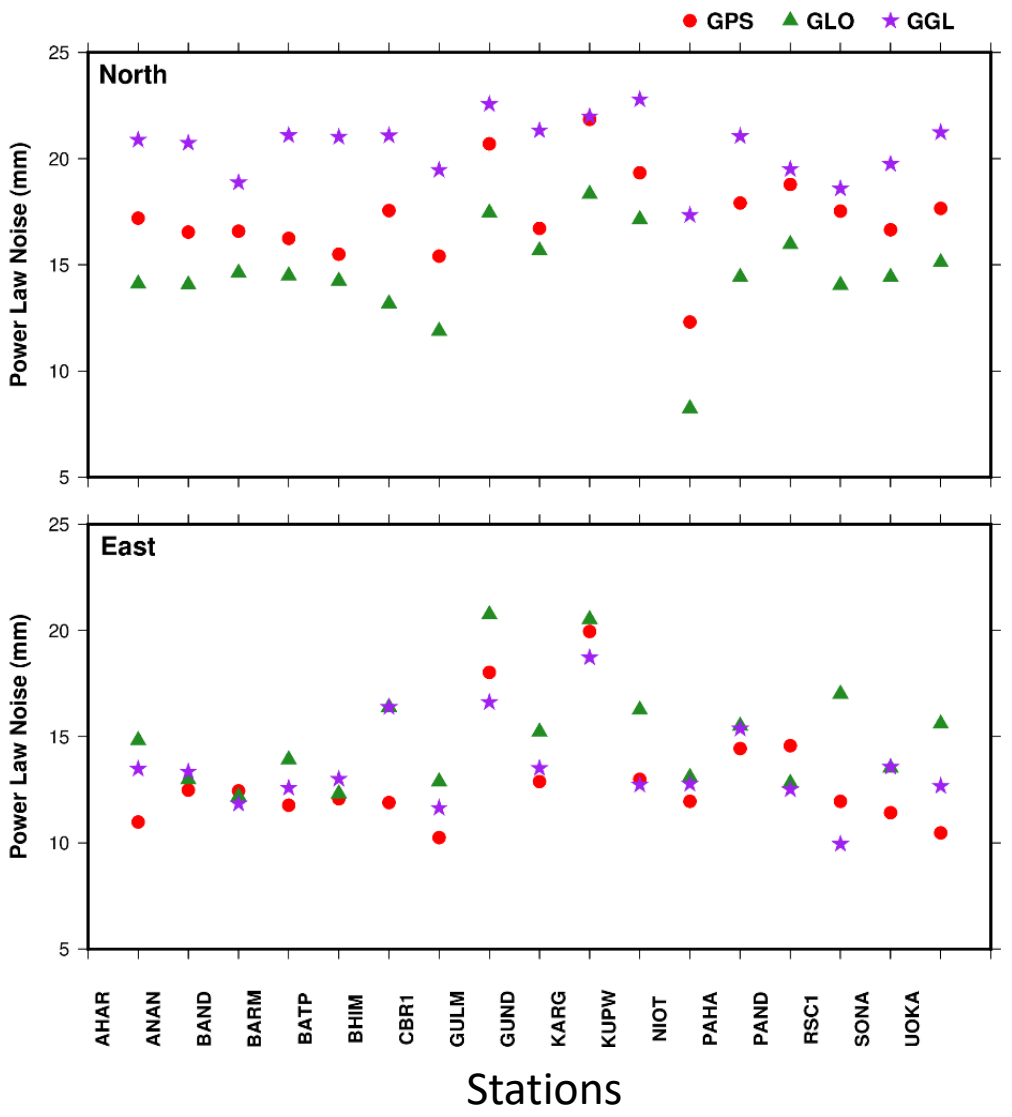
White noise

- Even though the velocity estimates are comparable, results show both the North & East component white noise levels are high for GLO & GGL compared to the GPS time series.
- Also noise levels are high for the stations with more multipath effect.

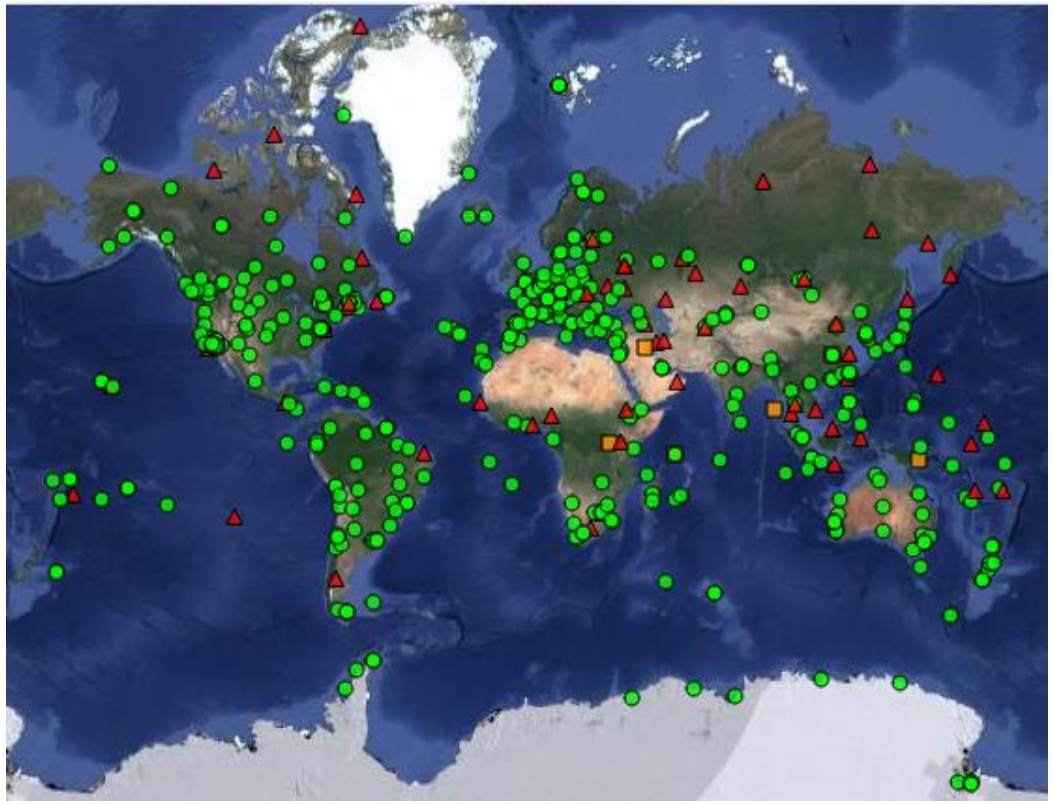


Power law Noise

- In north component, power law noise is more for GGL time series compared to GPS.
- GLO time series has the lowest noise which needs to be further investigated.
- In East component, noise is more for GLO time series compared to GGL, and GPS time series has lowest noise.



Latitude dependence on Noise amplitudes

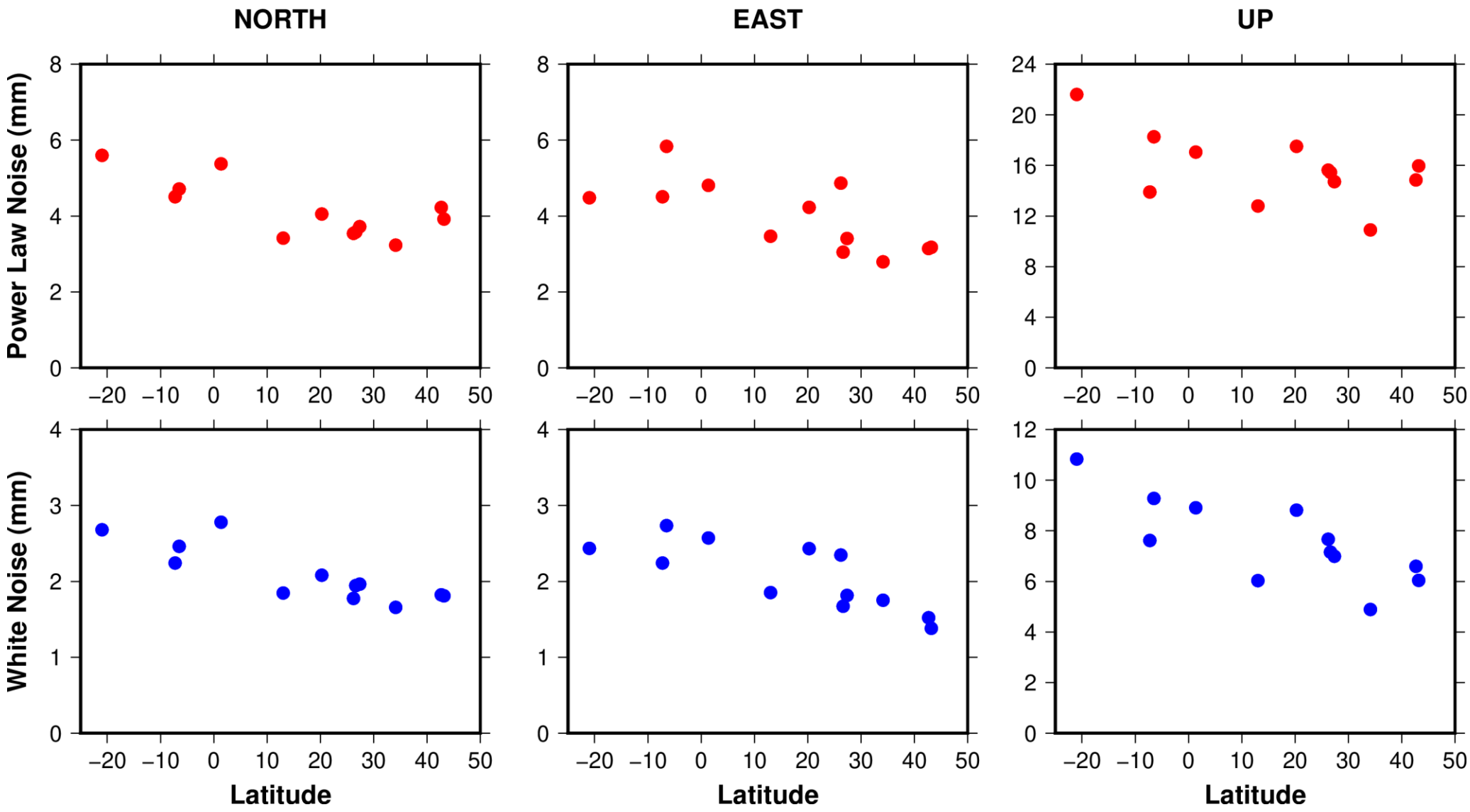


IGS network*

- Significant positive bias is observed for Southern hemisphere sites compared to sites in the Northern hemisphere (Williams et al. 2004).
- Sites near the equator have the noise with greatest amplitudes.

**Status on 03 December, 2022 as per IGS website*

Latitude dependence on noise amplitudes



White noise and Power law noise of sites (-25ºE to 45ºE)

Conclusion

- Study indicates that multi-GNSS data does not significantly improve the positional accuracy, but eliminates the dependency on a particular satellite system in the long term.
- Time series of multi-GNSS is much more stable than the single GNSS with errors.
- Noise levels are more in GLO and GGL compared to GPS, even though the velocity estimates are comparable.
- Noise values are high for the stations with more multipath effects (MP1 and MP2).

Future work

- Operational global constellations like Galileo, BeiDou data can be analysed in addition to the GPS and Glonass to study their impact on geodetic studies especially in Indian sub-continent.

THANK YOU