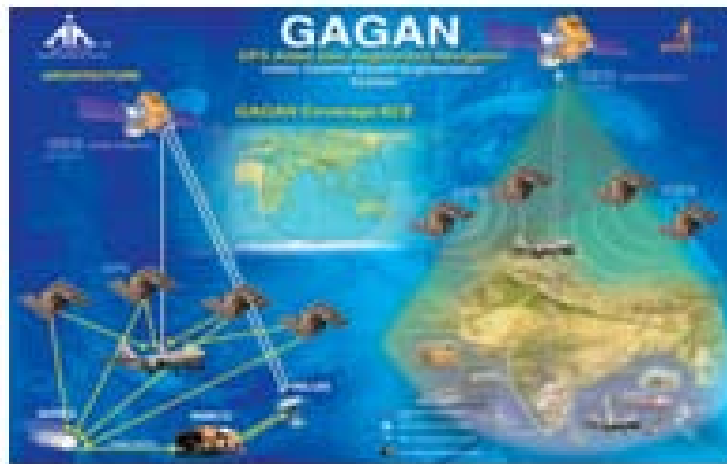


IONOSPHERIC BEHAVIOR DURING CURRENT SOLAR STORMS OVER INDIAN REGION



GAGAN-Redefining Navigation



IRNSS – A Self Reliant Navigation

**NIRMALA S
RETHIKA T
A S GANESHAN
ISRO SATELLITE CENTRE
BANGALORE**

**IWG #26 & ISTF #04
New Delhi-INDIA**

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- Depletion Studies

- **Observations**

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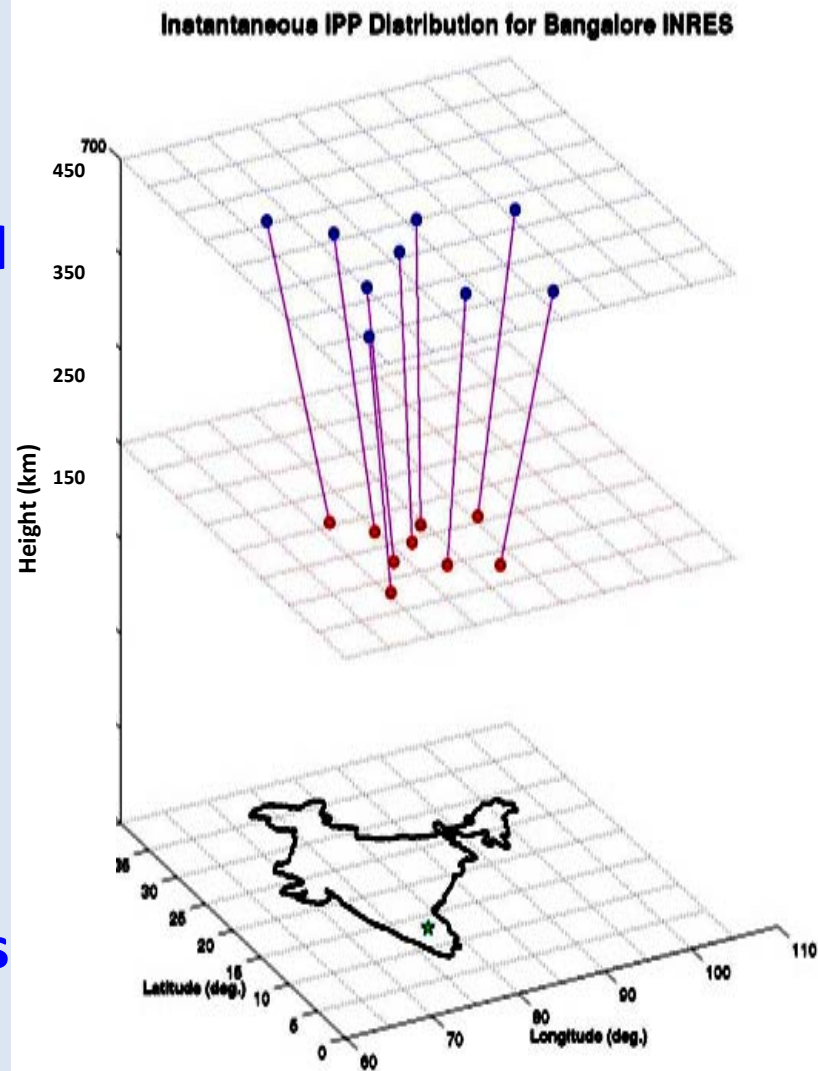
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ISRO GIVE Model - Multi Layer Data Fusion

IGM-MLDF (ISRO GIVE Model - Multi Layer Data Fusion):

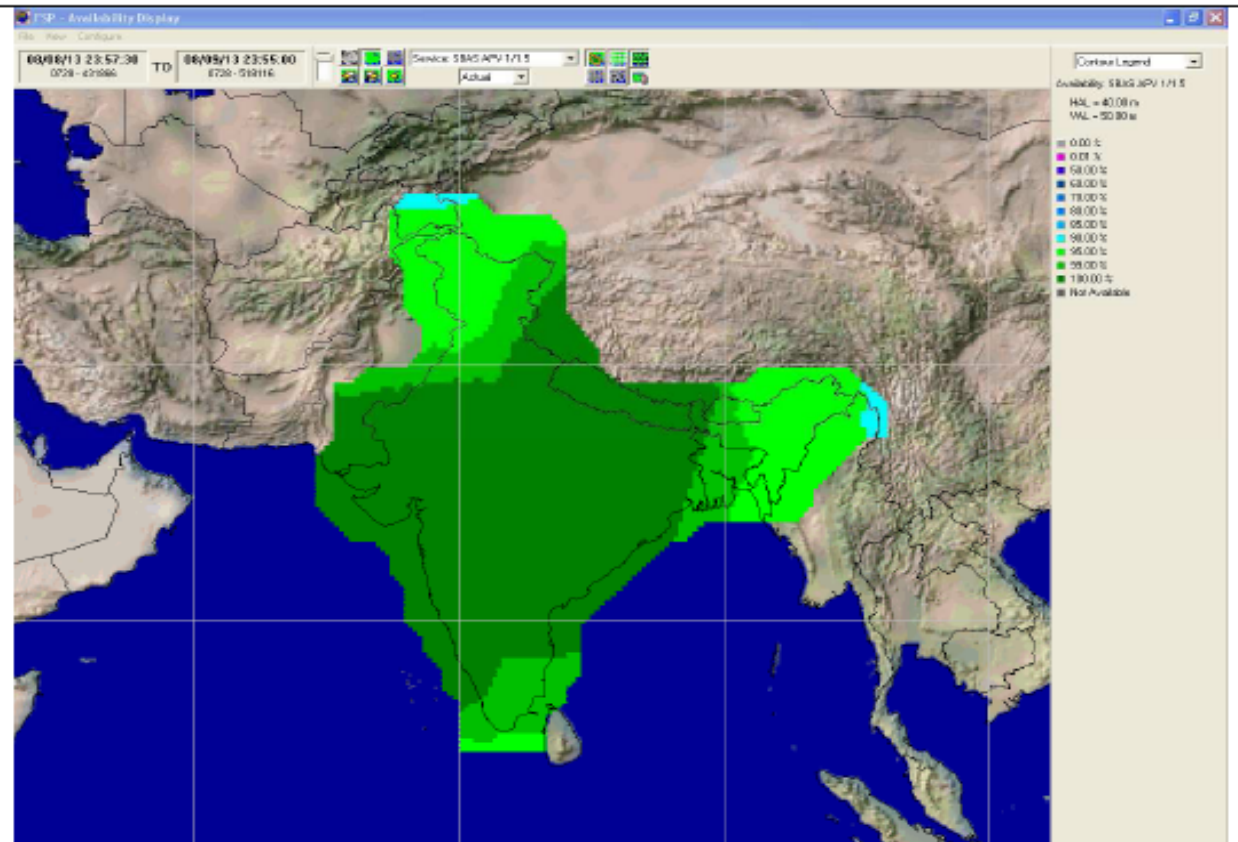
- Algorithm for computing the ionosphere corrections at pre-defined grid points
- Fuses the delays and confidences at two different layers
- Implemented into the GAGAN operational software to provide ionospheric corrections and integrity factors to meet the APV requirements
- Ensures better performance over single layer model



IGM-MLDF

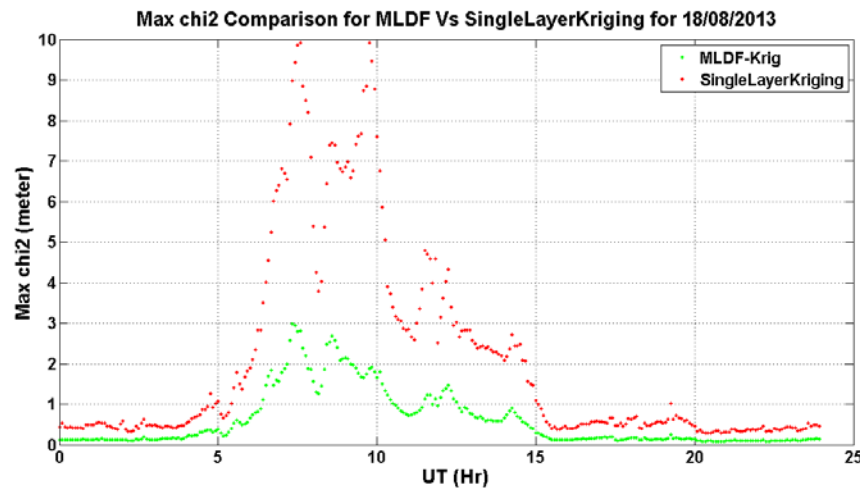
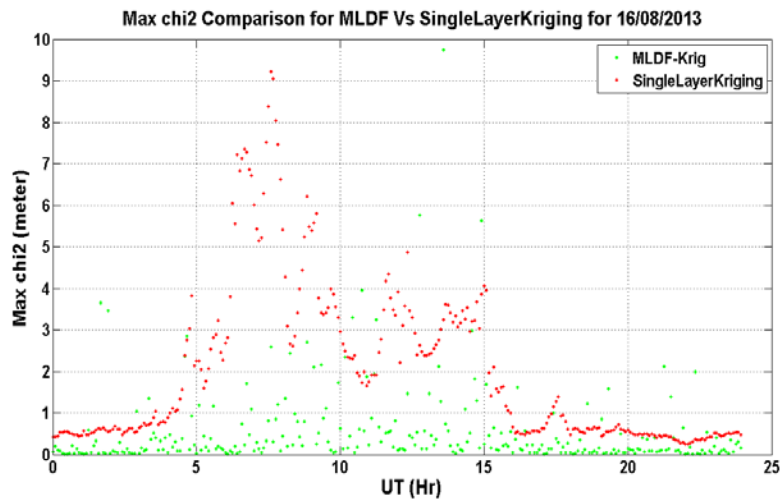
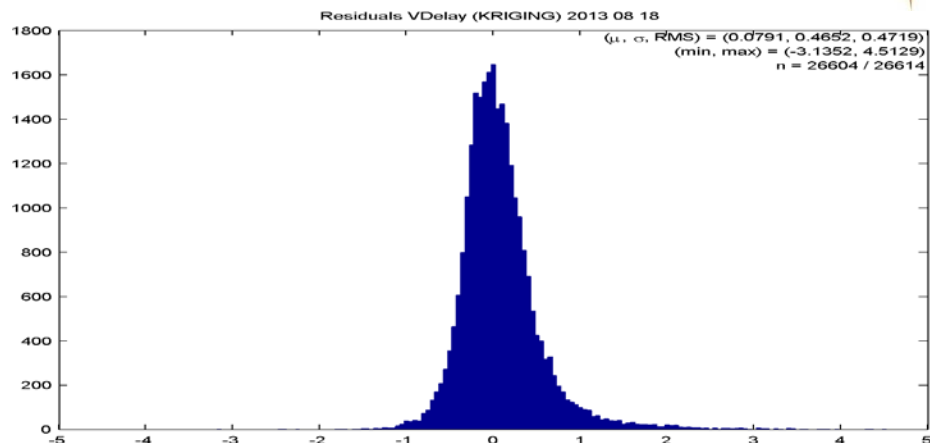
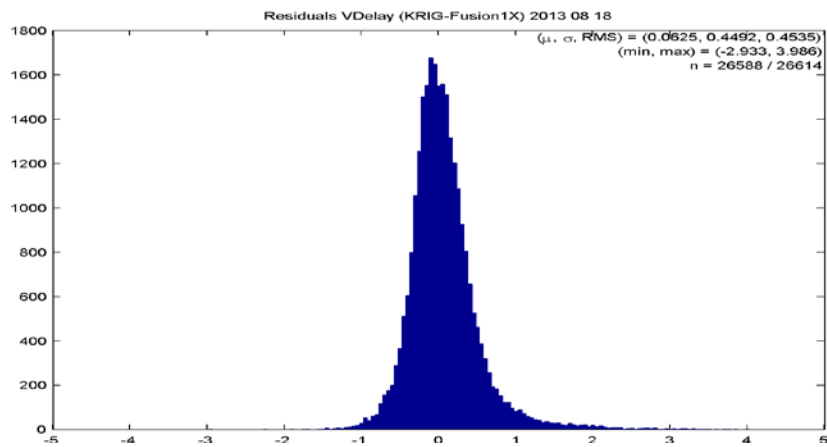
GAGAN Performance with IGM-MLDF

(A) GAGAN Service APV 1/1.5
Availability Coverage % at
95% Contour: 100.00
99% Contour: 85.54
100% Contour: 74.14



Date: 9th Aug 2013 (Nominal Day)
Max χ^2 : 1.769
 K_p : 2
Dst: > 0

Comparison of GRID iono corrections



Comparison of IGM-MLDF Vs Single Layer

Mean and RMS errors better for IGM-MLDF (better accuracy and integrity)

Chi2 metric less for IGM-MLDF (better availability)

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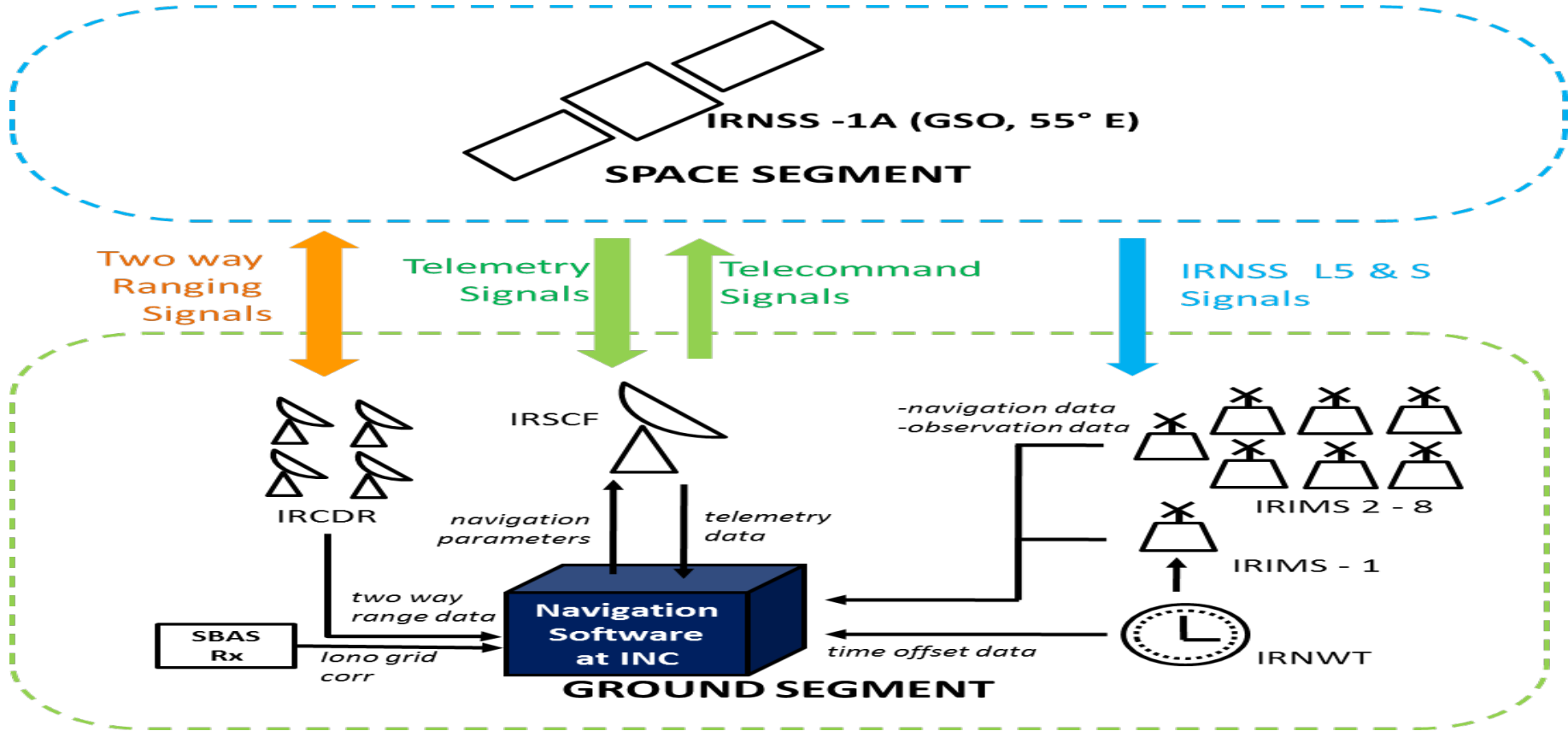
- Ionospheric delay on L5 (over Indian region)
- Grid based & Co-efficient based corrections for IRNSS
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- **Data Source**

- IRNSS measurements (L5 and S)
- GAGAN messages (L1 to L5)
- TEC data (L1 to L5)
- GAGAN INLUS data (L1 and L5)

IRNSS – Current Configuration



IRNSS Measurements:

- Code (L5, S)
- Carrier (L5, S)

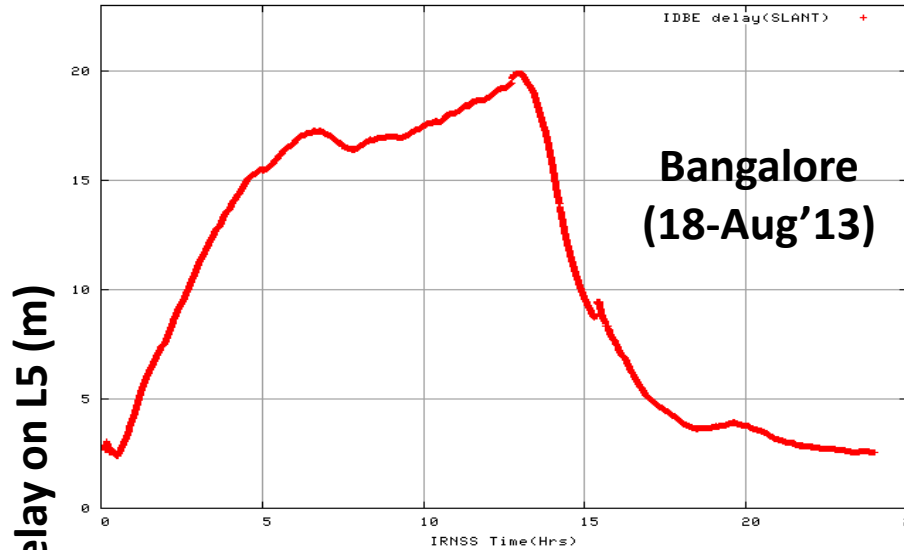
Ionospheric Corrections for IRNSS Single frequency Users:

- Grid Based (IIM)
- Co-efficient Based

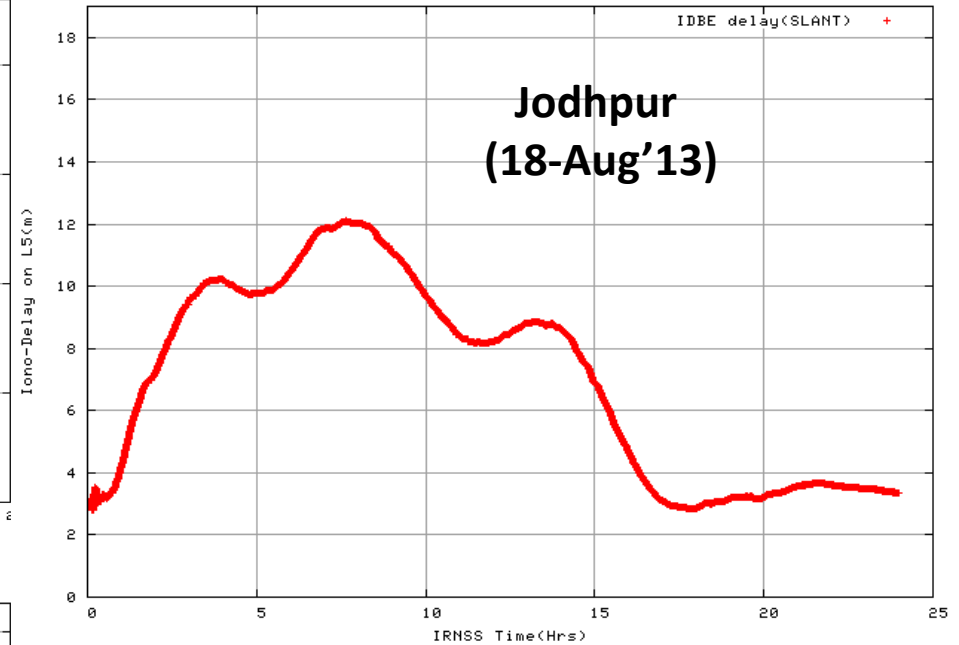
Ionospheric delay on L5 (IRNSS-1A)



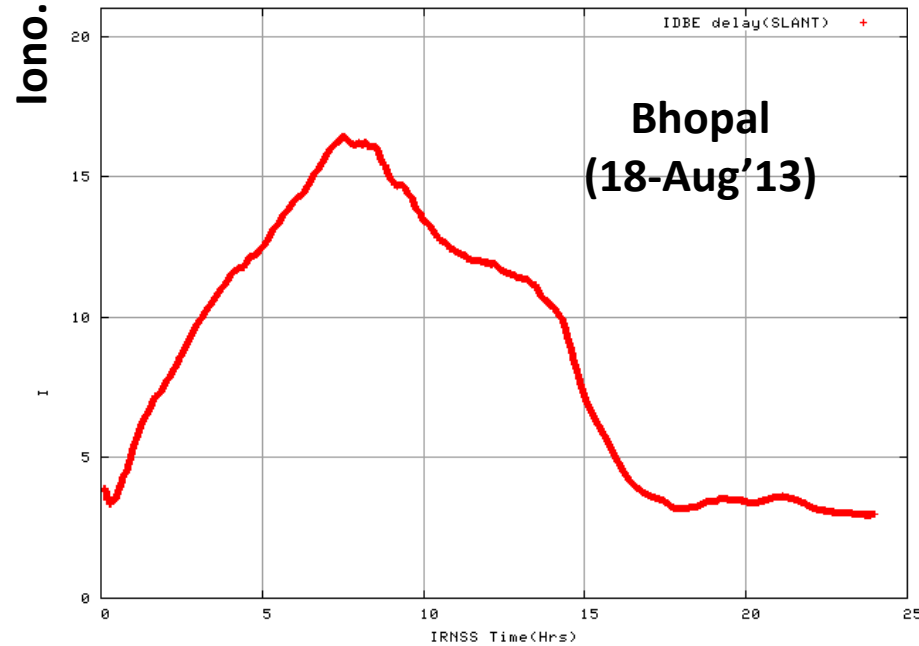
SLANT IONO DELAY FOR IDBE FOR STN: BANGALORE-A DOY:230



SLANT IONO DELAY FOR IDBE FOR STN: JODHPUR-A DOY:230



SLANT IONO DELAY FOR IDBE FOR STN: BHOPAL-A DOY:230



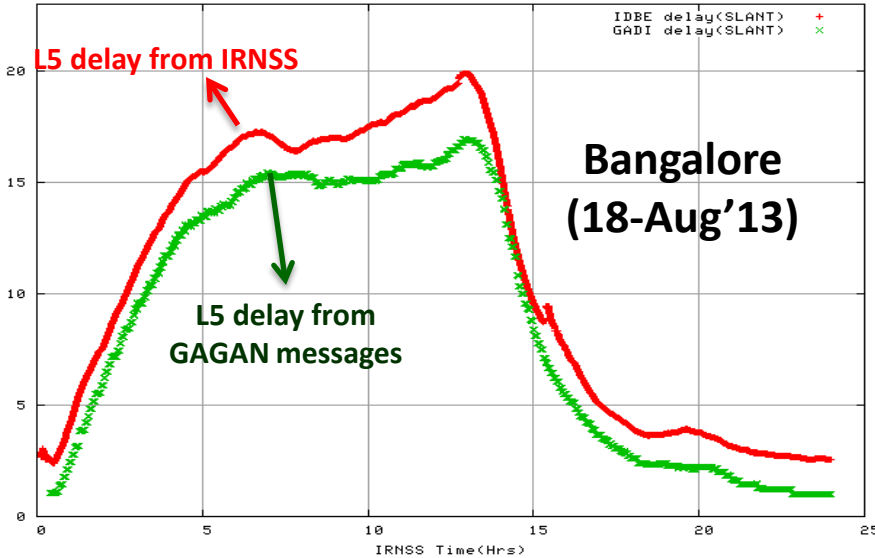
Validation of Ionospheric delays derived from L5-S frequencies!!!

Validation with GAGAN messages

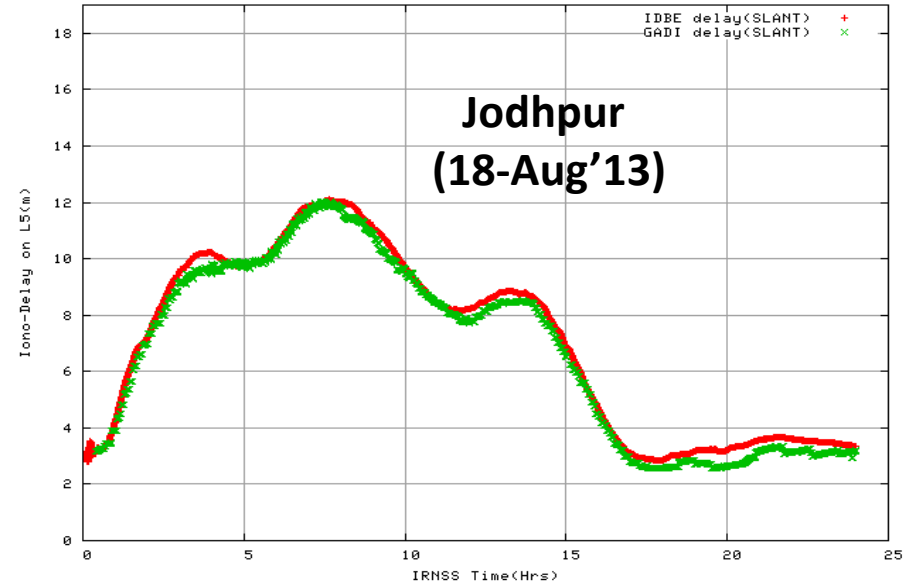


Iono-Delay on L5 (m)

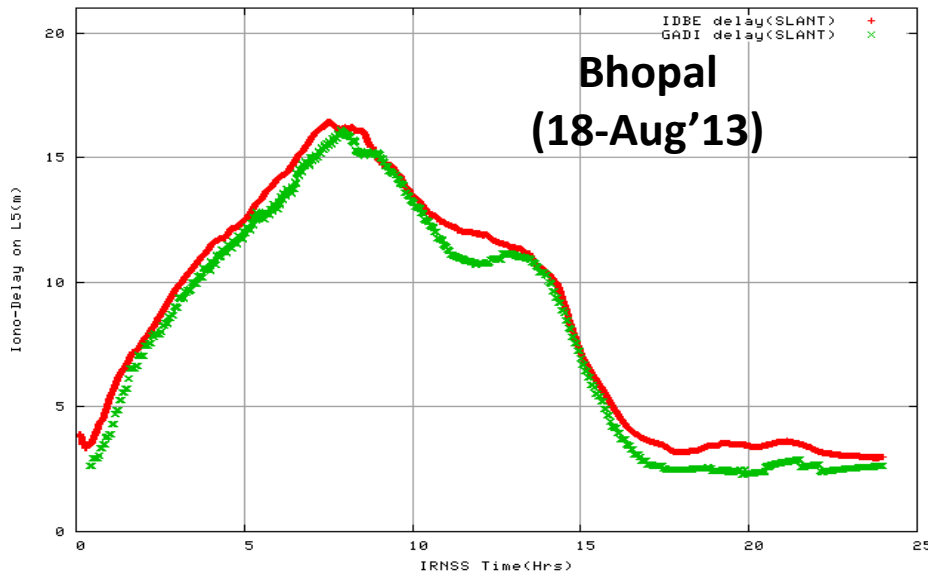
SLANT IONO DELAY FOR IDBE,GADI FOR STN:BANGALORE-A DOY:230



SLANT IONO DELAY FOR IDBE,GADI FOR STN:JODHPUR-A DOY:230

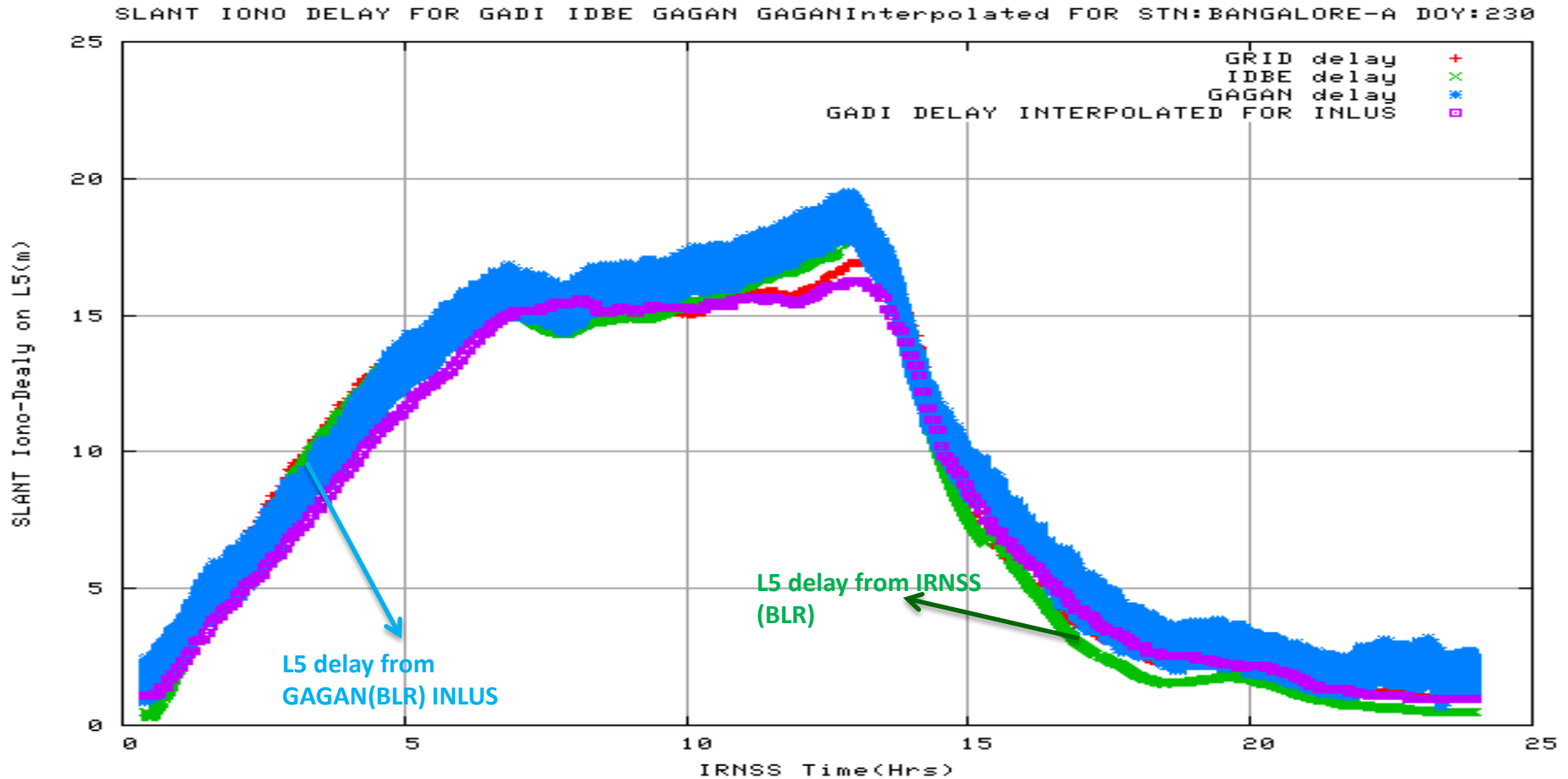


SLANT IONO DELAY FOR IDBE,GADI FOR STN:BHOPAL-A DOY:230



Delay variation derived (L5) from IRNSS validation using GAGAN messages

Validation with GAGAN INLUS data

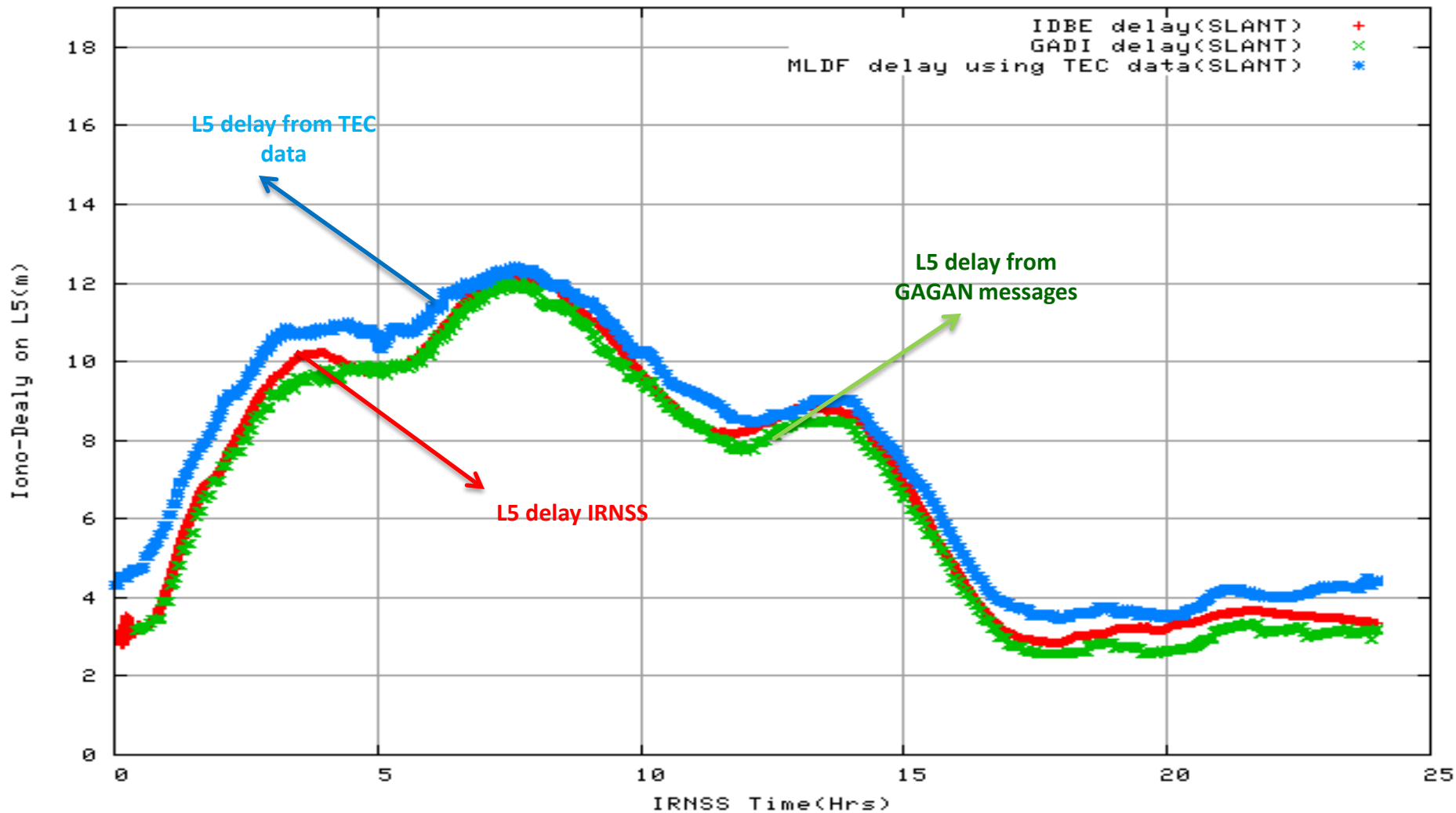


Delay variation derived (L5) from IRNSS validated using GAGAN INLUS (L5) data

Validation with GAGAN TEC data



SLANT IONO DELAY FOR IDBE,MLDF(TEC),GADI FOR STN:JODHPUR-A DOY:230



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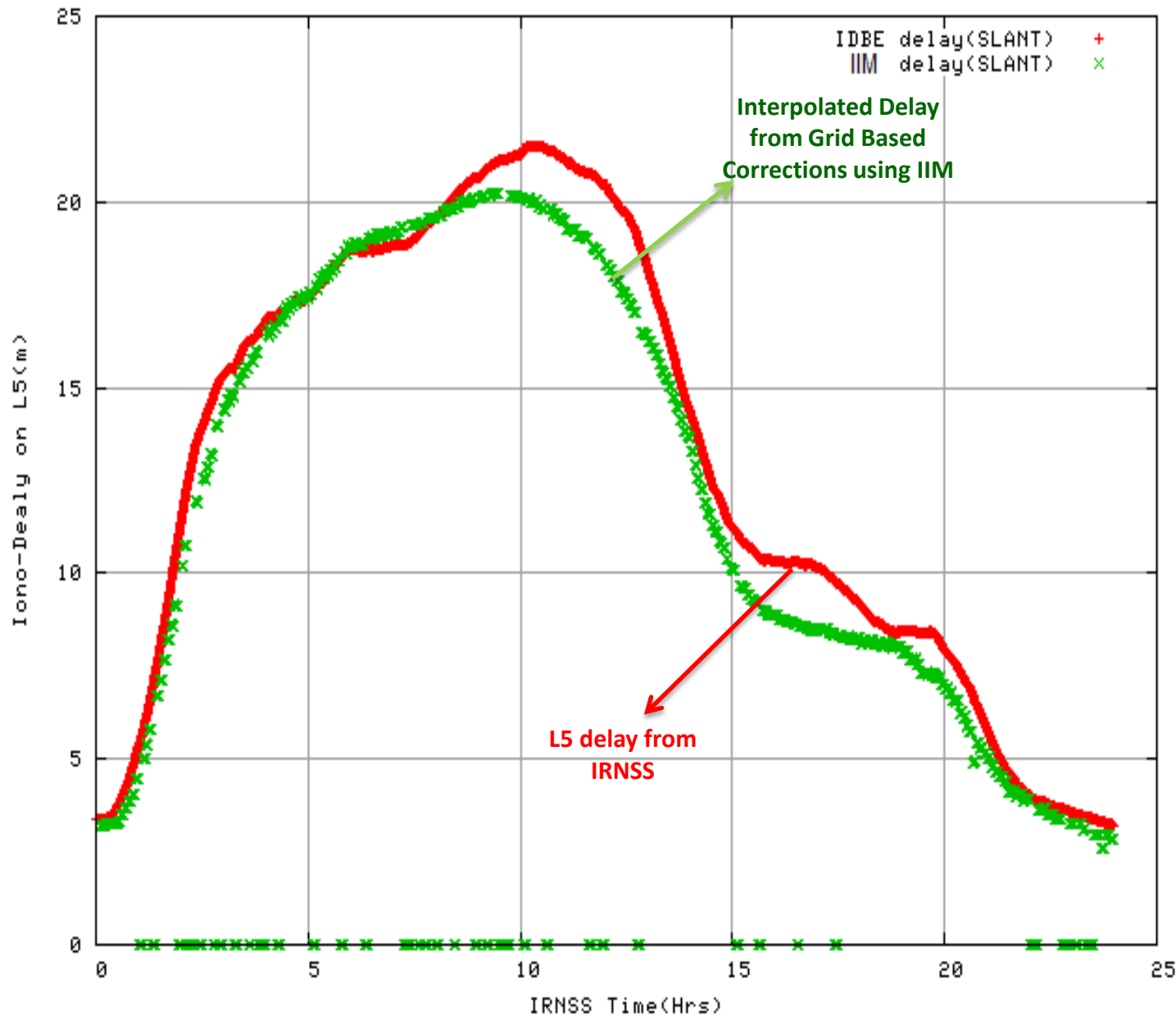
- Ionospheric delay on L5 (over Indian region)
- Grid based & Co-efficient based corrections for IRNSS
- Depletion and Scintillation on L5

- **Observations**

Grid Based Ionospheric Corrections For IRNSS



SLANT IONO DELAY FOR IDBE, IIM FOR STN:BANGALORE-A DOY:240

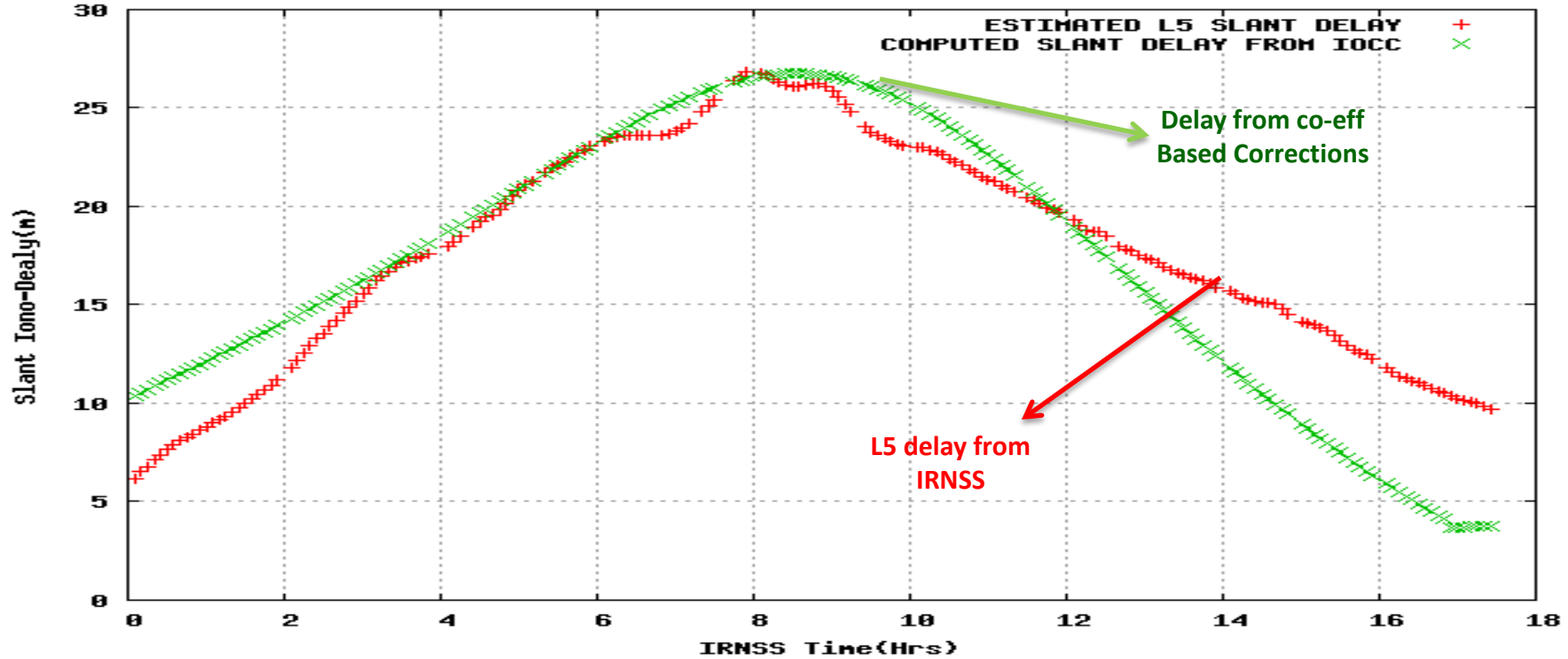


- Iono corrections derived for IRNSS using sparse input measurements.
- Accuracy expected to improve with more measurements

Co-efficient Based Ionospheric Corrections For IRNSS



SLANT IONOSPHERIC DELAY COMPARISON FOR STN:PORTBLAIR-A DOY:276



Error Statistics for Iono coeff for 3/10/2013 (calm period excluded)

Error	Mean (m)	Std.dev (m)	RMS (m)
GPS Klobuchar coefficients	12.7529	4.7900	13.6228
IRNSS ionospheric coefficients	3.0433	3.5050	4.6418

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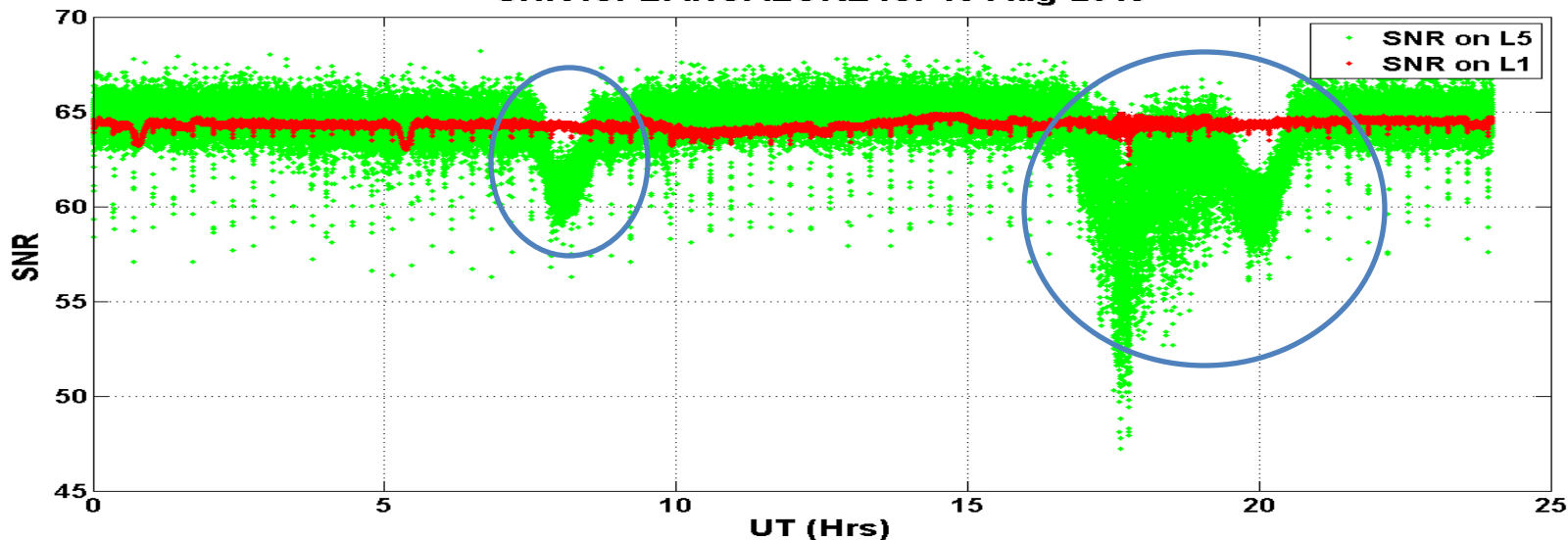
- Observations

Scintillations over Indian Region

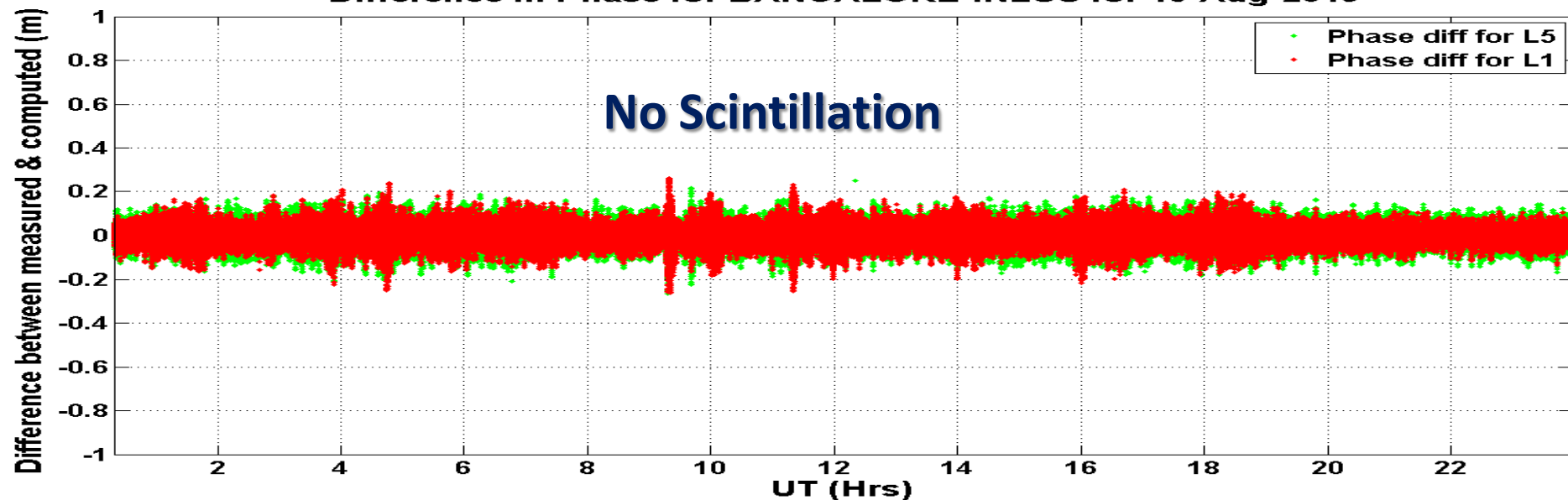


Scintillation Vs C/No (Bangalore (GAGAN) INLUS data (NOVATEL G2 Rx))

SNR for BANGALORE for 16-Aug-2013



Difference in Phase for BANGALORE-INLUS for 16-Aug-2013

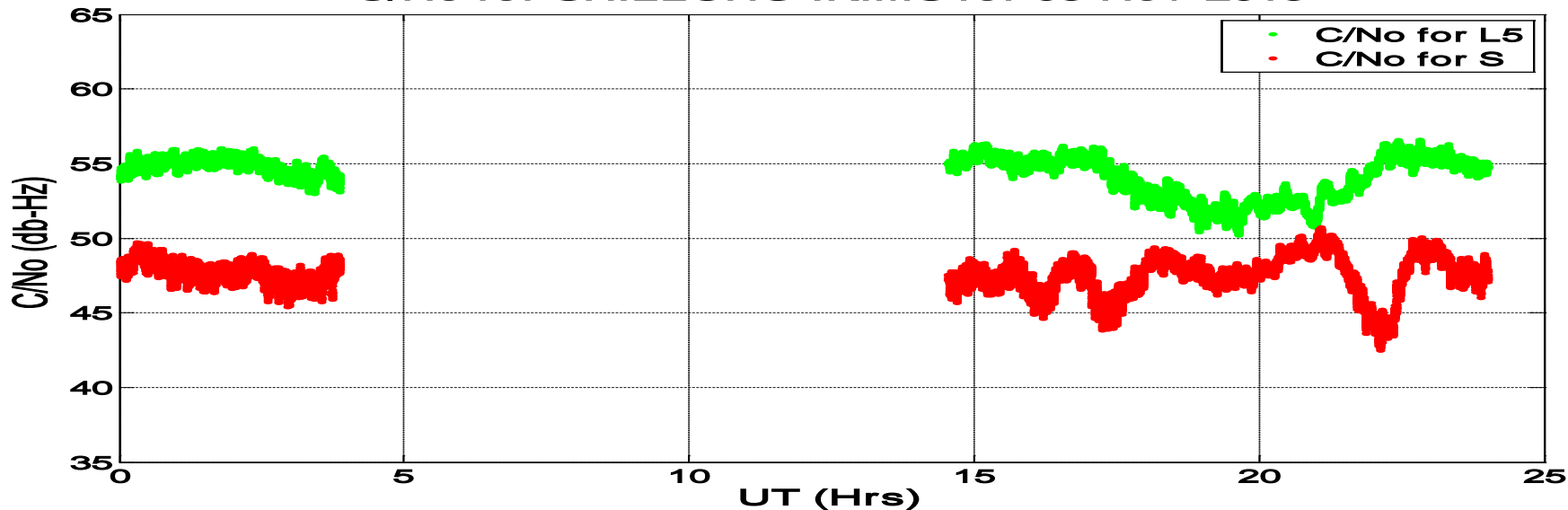


Scintillations over Indian Region

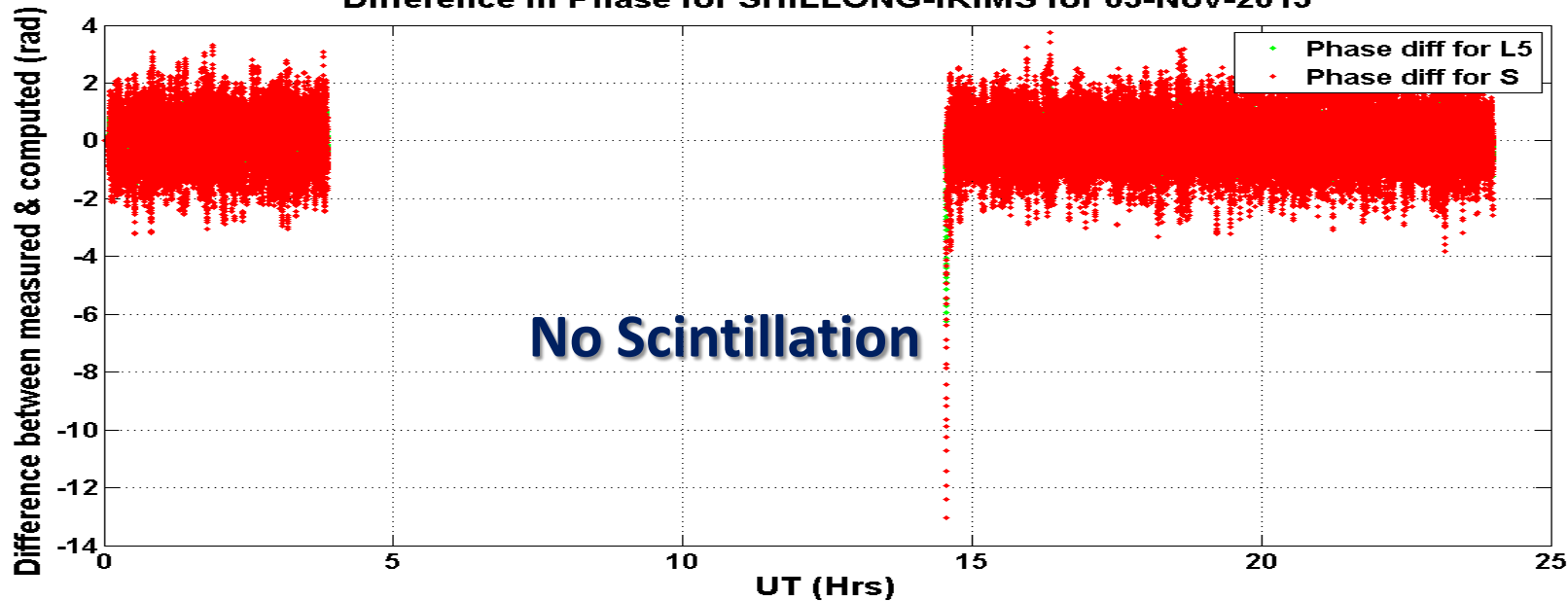


Scintillation Vs C/No (IRIMS SHILLONG(IRNSS) data (NOVATEL G3 Rx)

C/No for SHILLONG-IRIMS for 03-Nov-2013



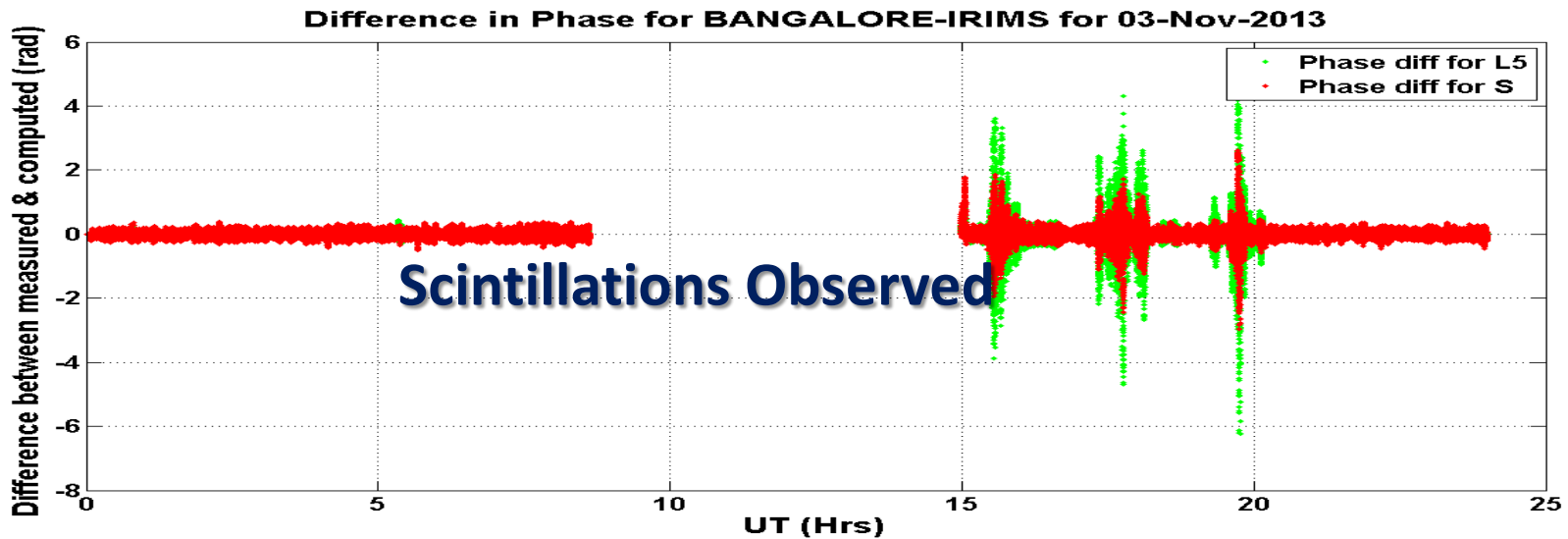
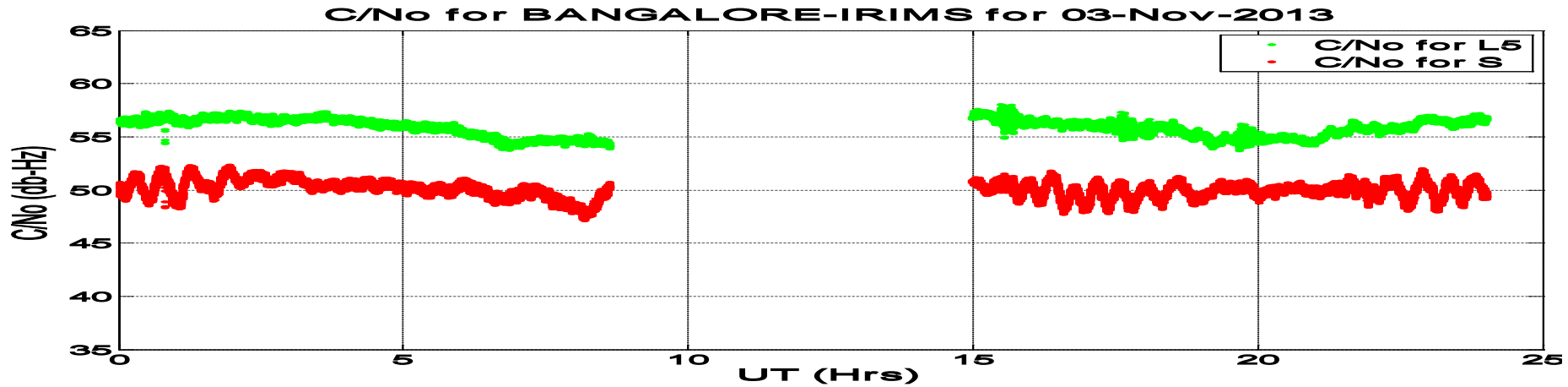
Difference in Phase for SHILLONG-IRIMS for 03-Nov-2013



Scintillations over Indian Region



Scintillation Vs C/No (IRIMS Bangalore (IRNSS) data (NOVATEL G3 Rx)



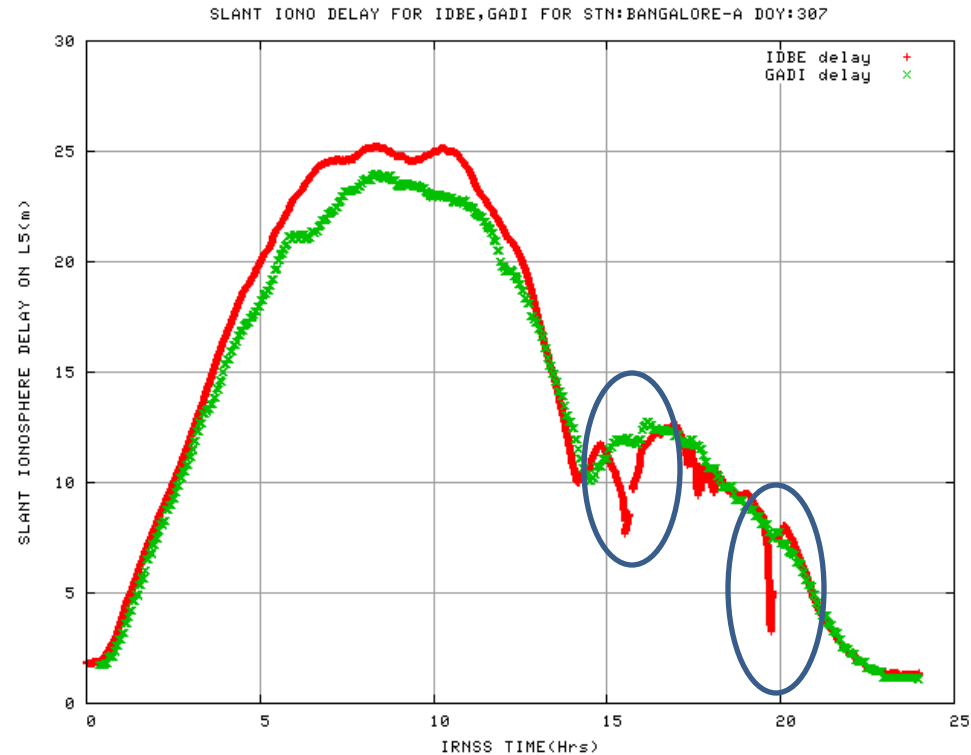
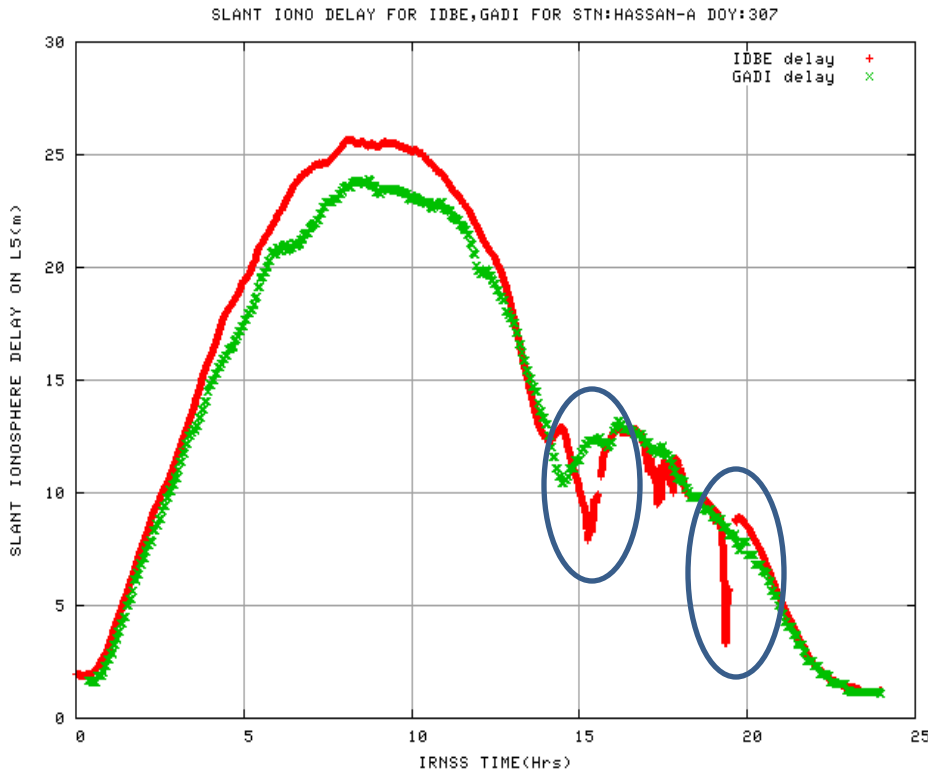
- Scintillation not observed which is taken care by G3 receiver.
- No loss of lock observed in any of the L5 measurements.
- Scintillation observed only through phase processing.

Depletions with IRNSS-1A Measurements



Hassan: (3 Nov 2013)

Bangalore: (3 Nov 2013)



Depletion depth: 5m

Depletion time: 15.25 UT (8.45 pm IST)

Depletion depth: 5m

Depletion time: 15.5 UT (9 pm IST)

Note that the scintillation has occurred during the same period and at the same locations where depletions were observed, but the signal strength of the L5 and S is still maintained

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Observations



- **The GAGAN APV performance being achieved using the IGM-MLDF for the nominal days**
- **The ionosphere delay derived from L5 and S frequencies for the first time and validated with various measurement sources**
- **Computation of ionospheric corrections with sparse data for IRNSS looks promising: Further improvements expected with more measurements**
- **L5 signal strength not disturbed during equinox (G3 Rx) and no LOL observed**
- **Further analysis with other type of Rx required**

Thank you