L-band scintillation studies in the Indian sector using GPS network

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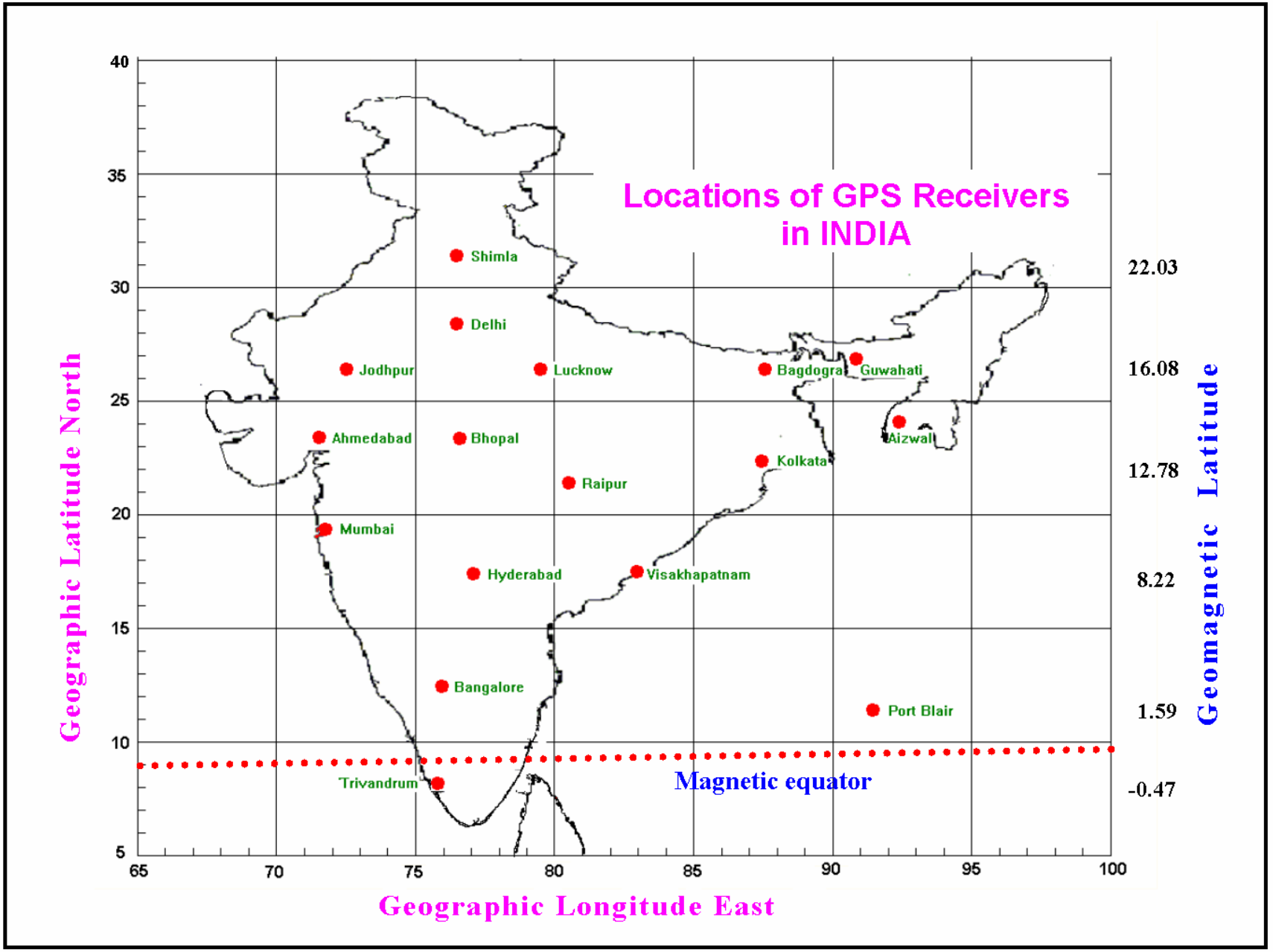
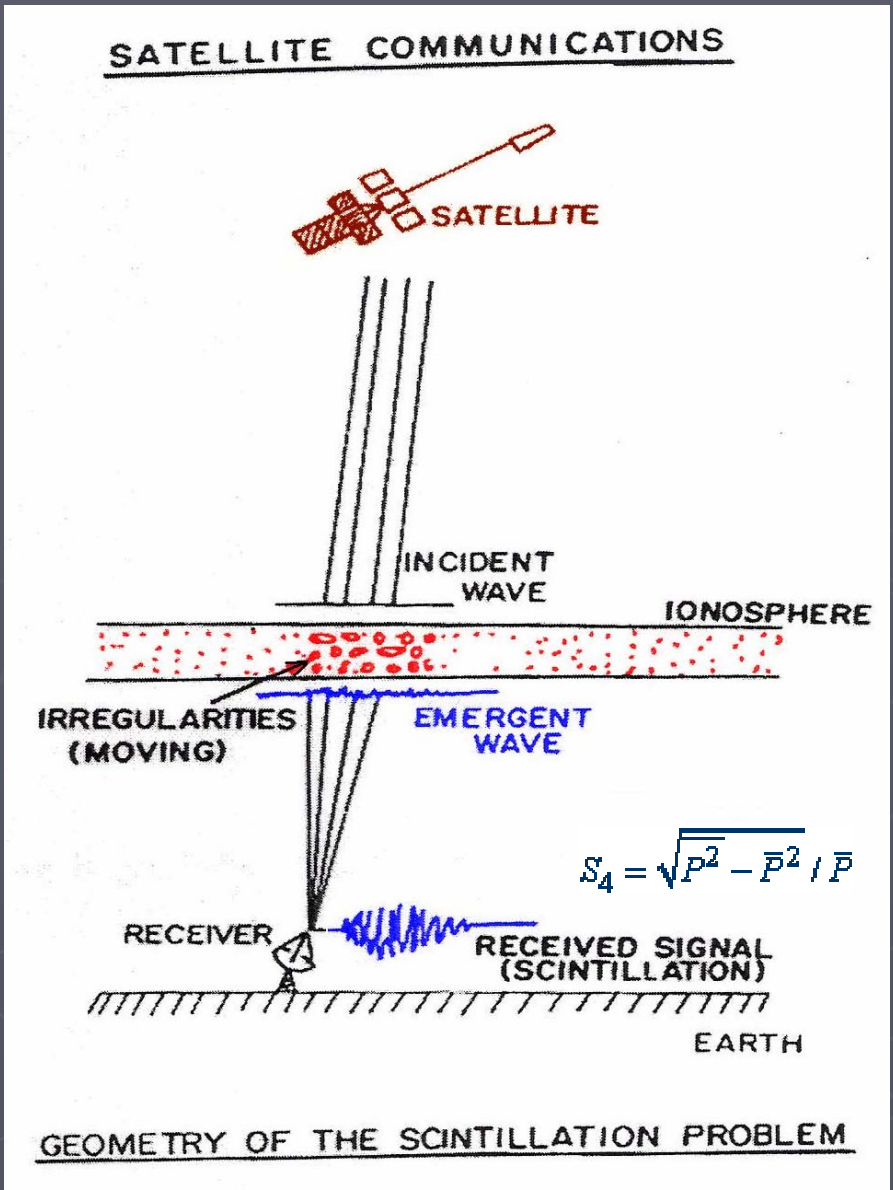

Locations of GPS Receivers in INDIA
Shimla
Delhi
Jodhpur
Lucknow
Bagdogra
Guwahati
Aizwal
Ahmedabad
Bhopal
Kolkata
Raipur
Mumbai
Hyderabad
Visakhapatnam
Bangalore
Port Blair
Trivandrum
Magnetic equator
Geographic Latitude North
Geomagnetic Latitude
22.03
16.08
12.78
8.22
1.59
-0.47
40
35
30
25
20
15
10
5
65
70
75
80
85
90
95
100
Geographic Longitude East

Irregularly structured ionospheric regions can cause diffraction and scattering of trans-ionospheric radio signals. When received at an antenna, these signals present random temporal fluctuations in both amplitude and phase. This are known as ionospheric scintillations

S4 index is defined as the root mean square of the signal to noise ratio

Amplitude scintillations can be monitored by the time series of S/N values provided by the GPS receiver output

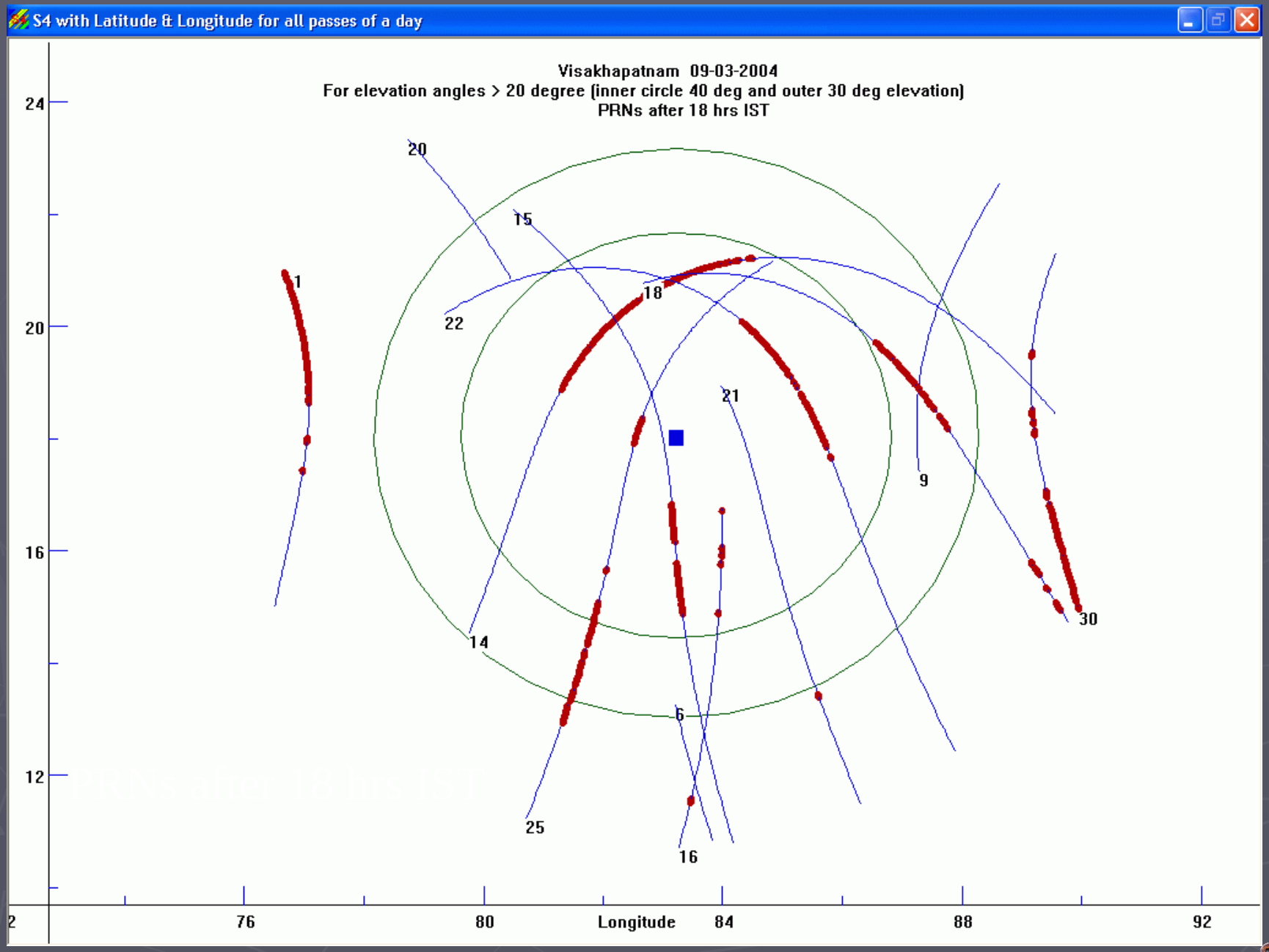


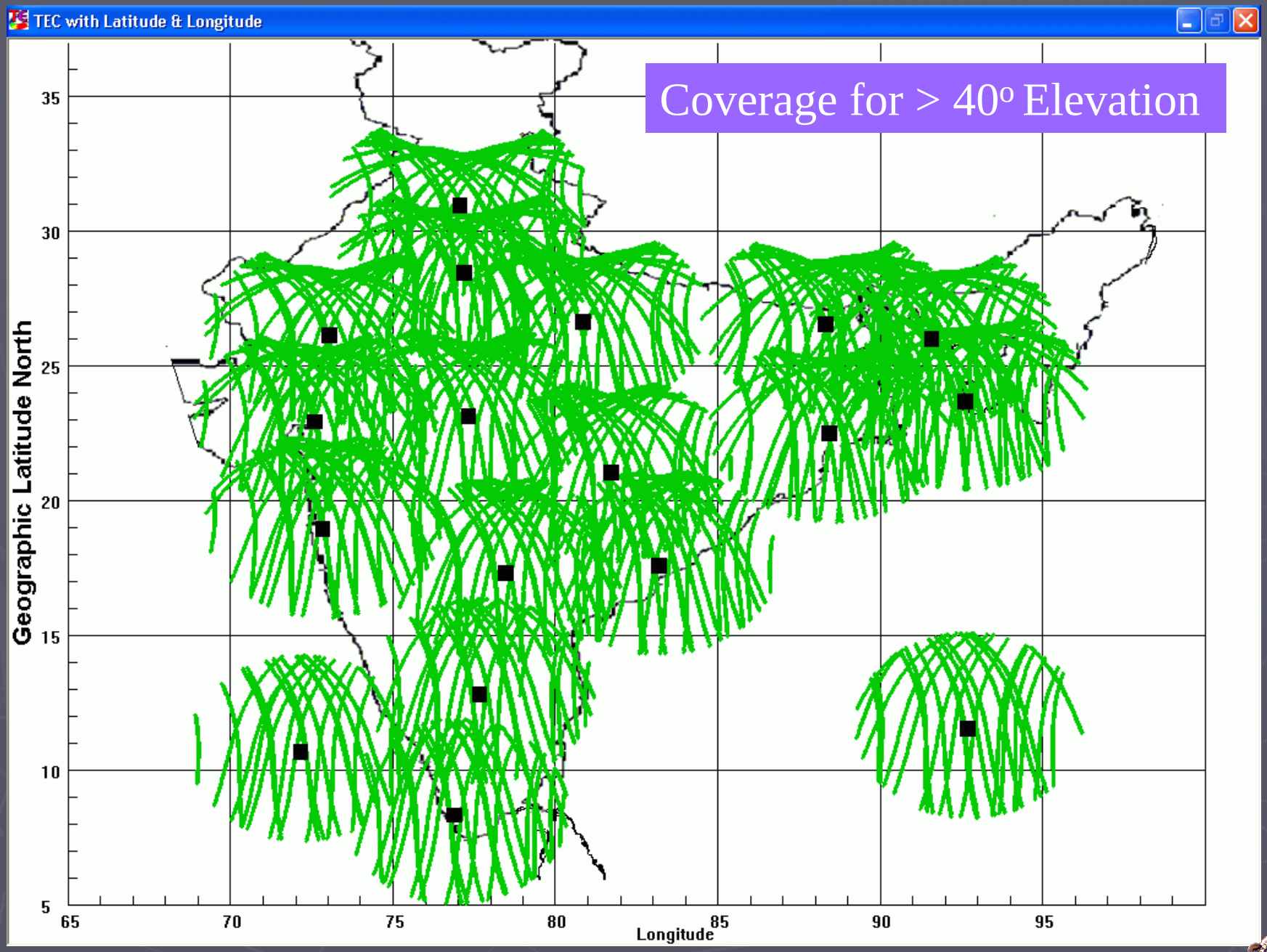
The strong amplitude scintillation may cause the received signal power to drop below the receiver's threshold limit, and then a loss of lock is observed.

And moreover, loss of signal lock at SBAS monitoring stations can degrade the broadcast correction information.

Though generally of negligible effect at mid-latitudes, scintillation effects can be a significant problems at low latitudes, particularly right after sunset

GPS satellite ionospheric pierce points (IPP) showing the spatial coverage of the data at a tropical station during the day


S4 with Latitude & Longitude for all passes of a day
Visakhapatnam 09-03-2004
For elevation angles > 20 degree (inner circle 40 deg and outer 30 deg elevation)
PRNs after 18 hrs IST
24
20
16
12
2
76
80
Longitude
84
88
92
20
15
1
18
22
21
9
30
14
6
25
16



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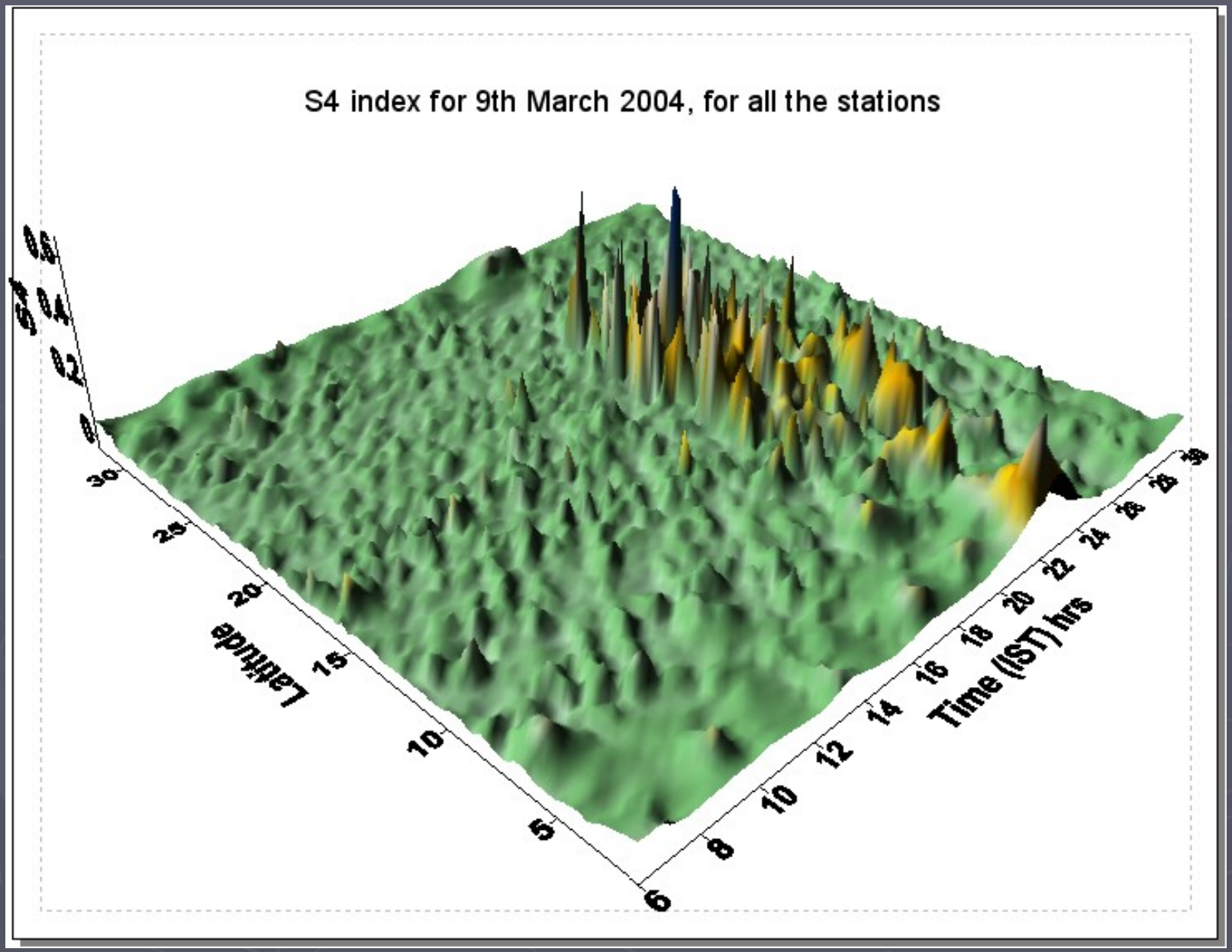
Occurrence of S4 index with Latitude and time for 9th March 2004



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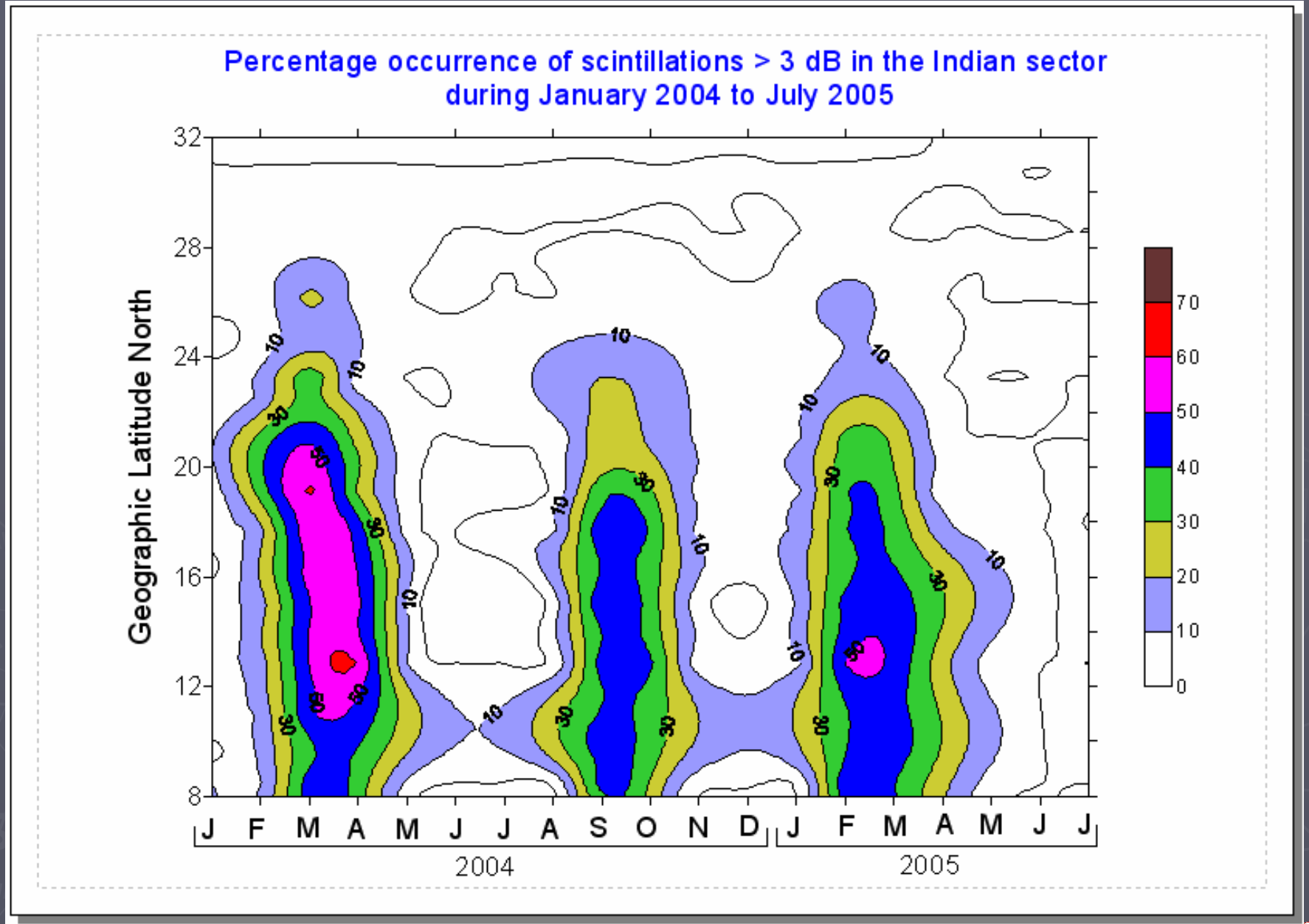
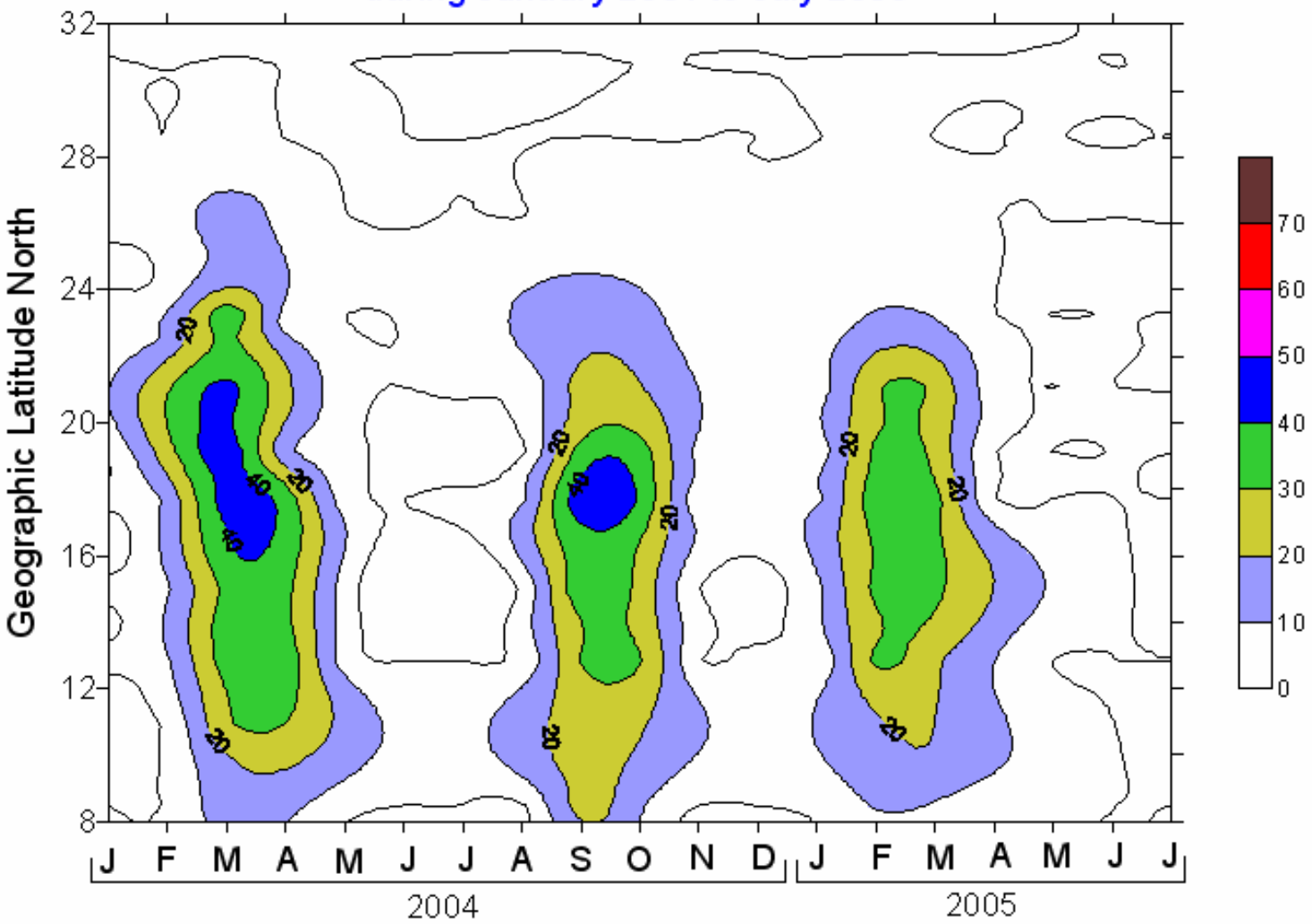
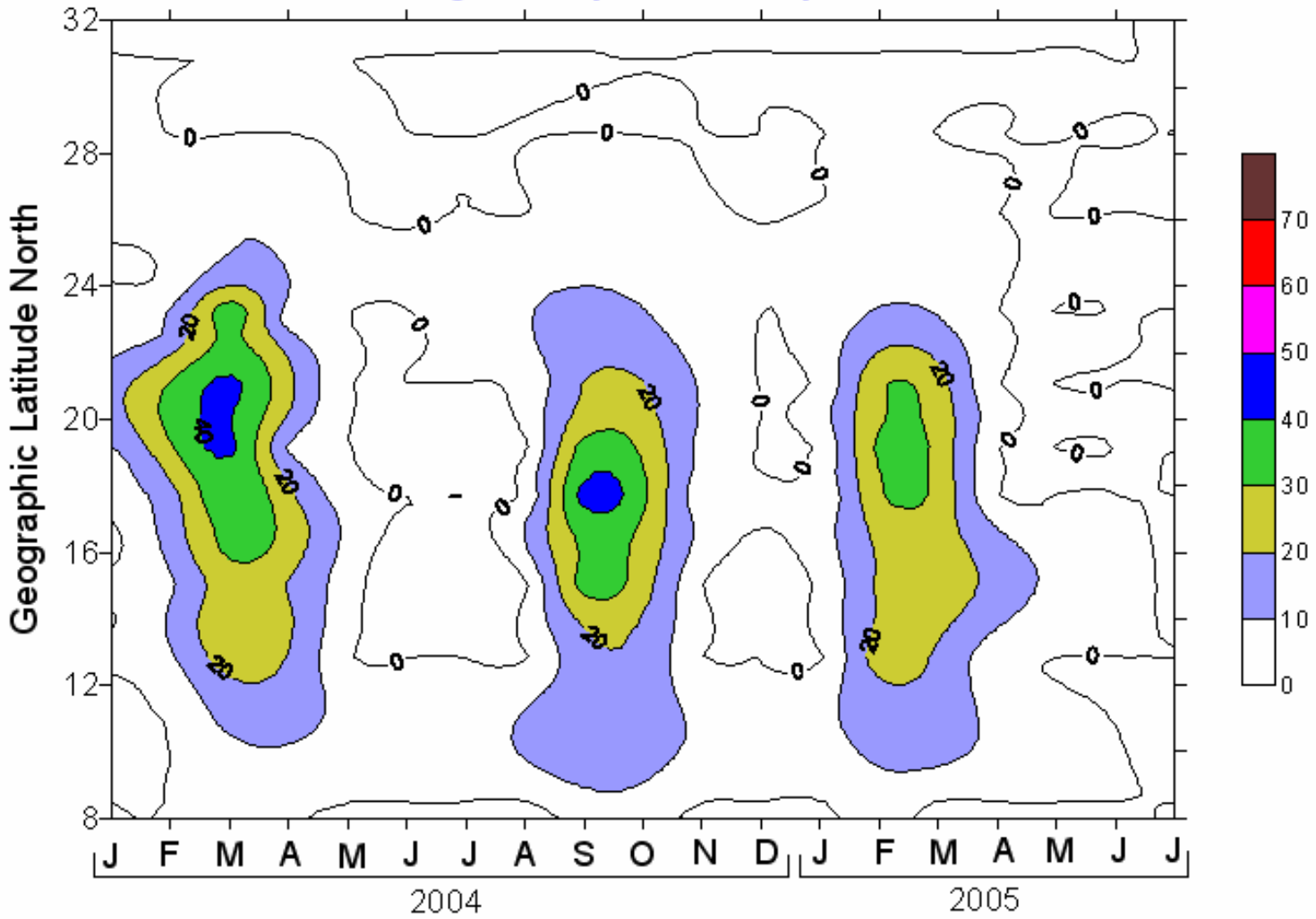
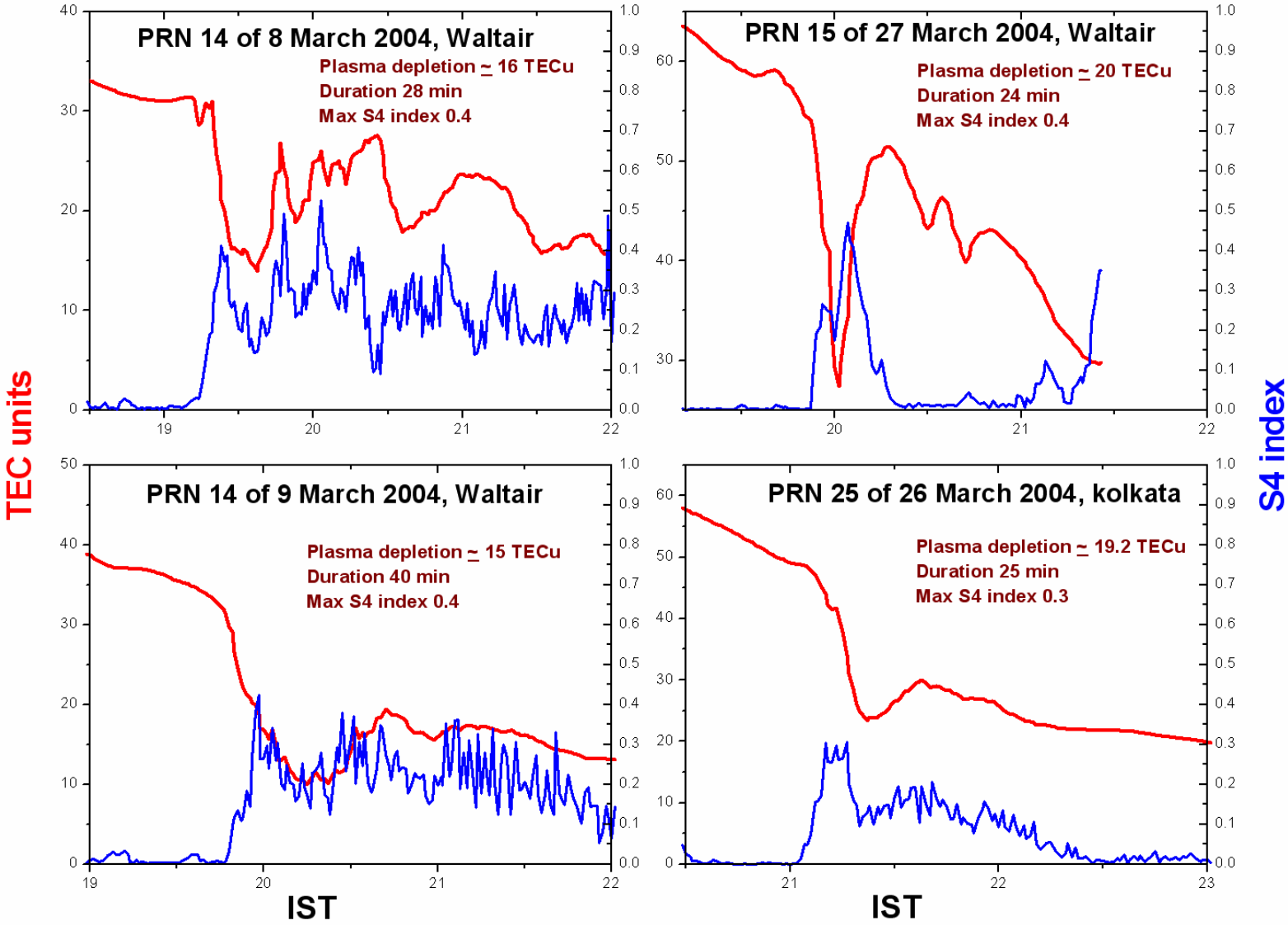

Percentage occurrence of scintillations > 3 dB in the Indian sector
during January 2004 to July 2005
Geographic Latitude North
32
28
24
20
16
12
8
J F M A M J J A S O N D
2004
J F M A M J J
2005
70
60
50
40
30
20
10
0


Percentage occurrence of scintillations > 6 dB in the Indian sector
during January 2004 to July 2005
Geographic Latitude North
32
28
24
20
16
12
8
J F M A M J J A S O N D
2004
J F M A M J J
2005
70
60
50
40
30
20
10
0

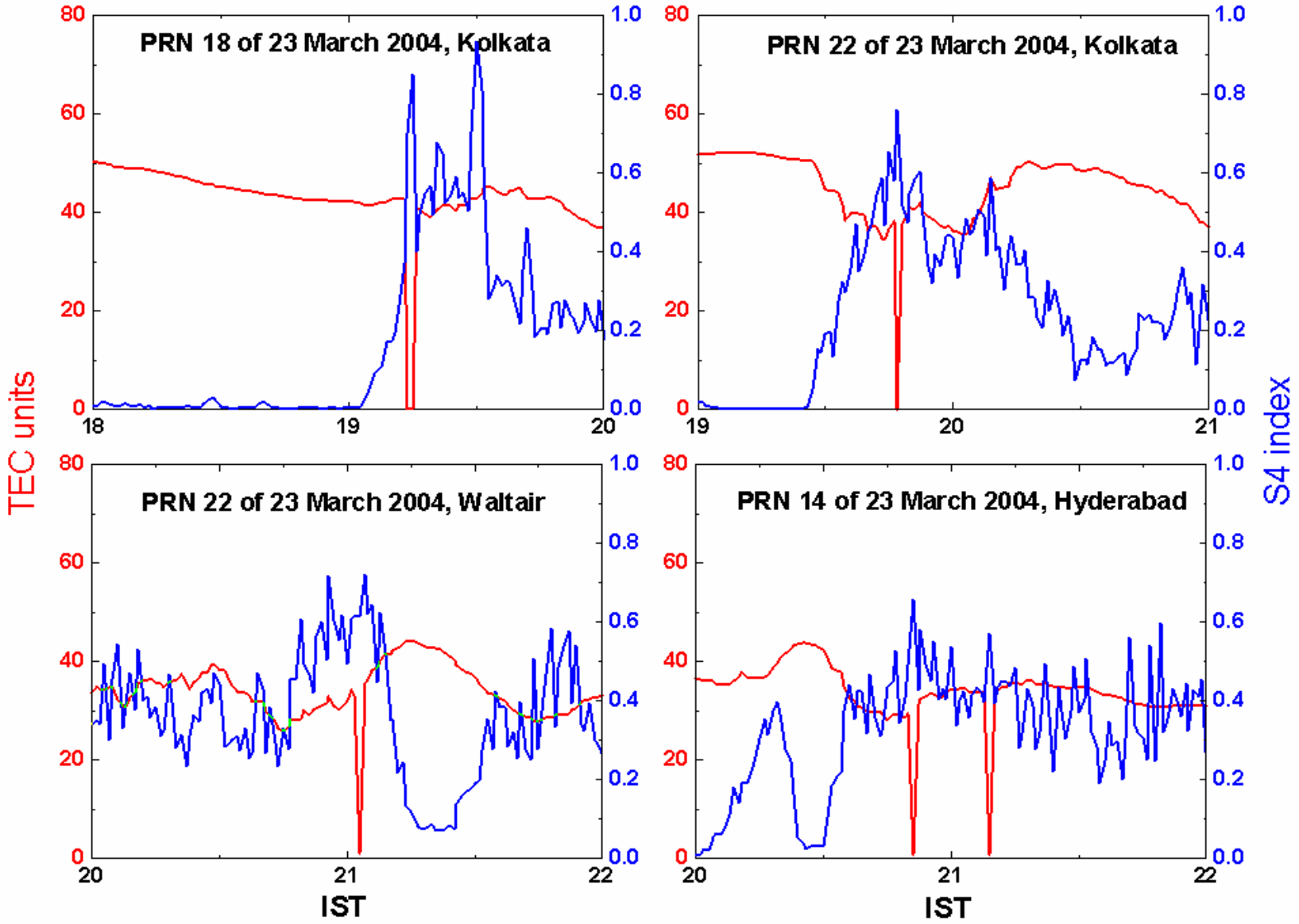

Percentage occurrence of scintillations > 10 dB in the Indian sector
during January 2004 to July 2005
Geographic Latitude North
32
28
24
20
16
12
8
J F M A M J J A S O N D J F M A M J J
2004
2005
70
60
50
40
30
20
10
0

Typical examples of TEC depletions and the corresponding S4 index



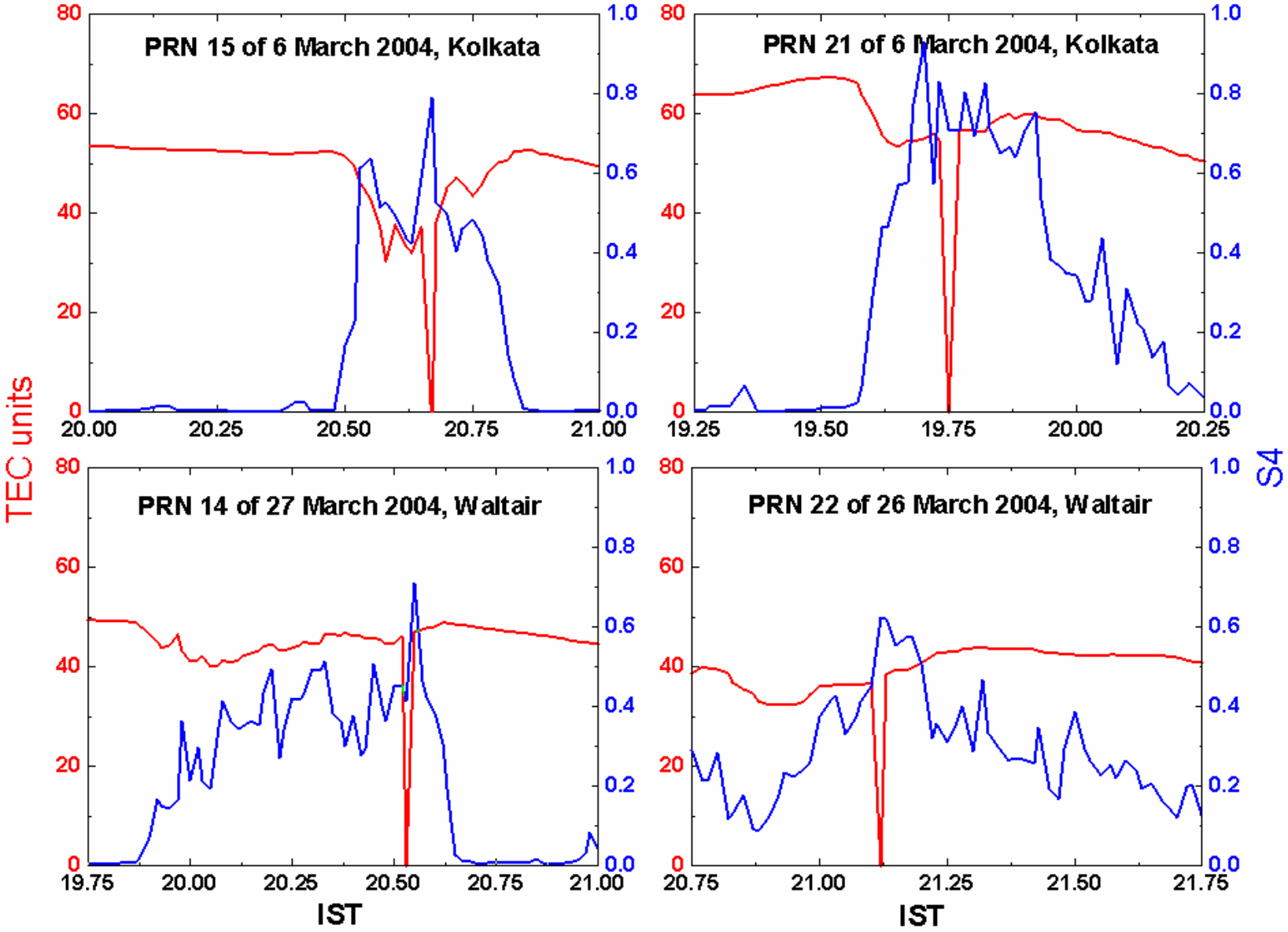
Typical examples of TEC depletions observed and the corressponding S4 index variations

Typical examples of Loss of lock of GPS receivers observed

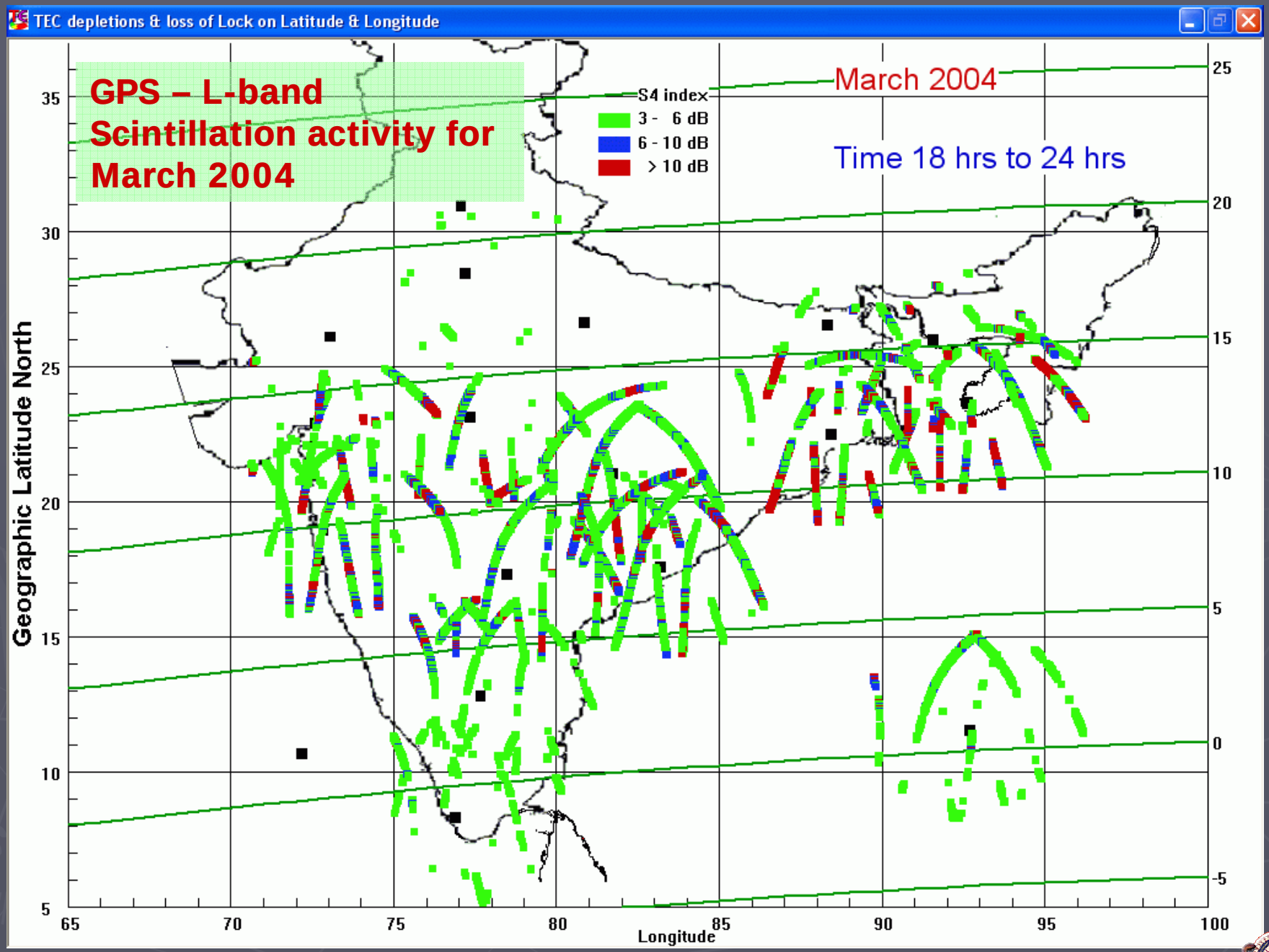


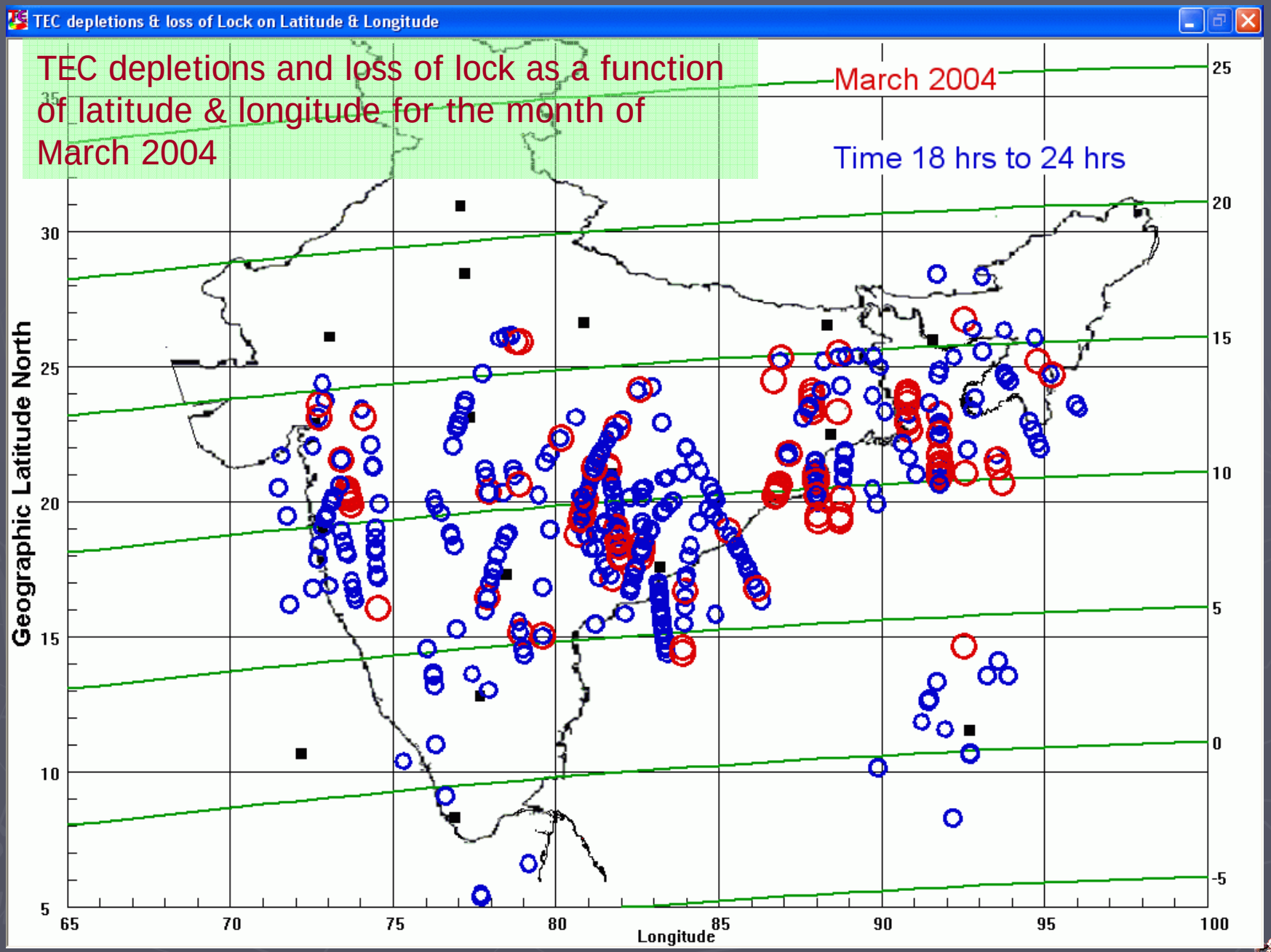
Typical Examples of the loss of lock of the GPS receivers

Typical examples of Loss of lock of GPS receivers observed



Typical Examples of the loss of lock of the GPS receivers


TEC depletions & loss of Lock on Latitude & Longitude
GPS – L-band Scintillation activity for March 2004
March 2004
Time 18 hrs to 24 hrs
S4 index
3 - 6 dB
6 - 10 dB
> 10 dB
Geographic Latitude North
Longitude
35
30
25
20
15
10
5
65
70
75
80
85
90
95
100
25
20
15
10
5
0
-5



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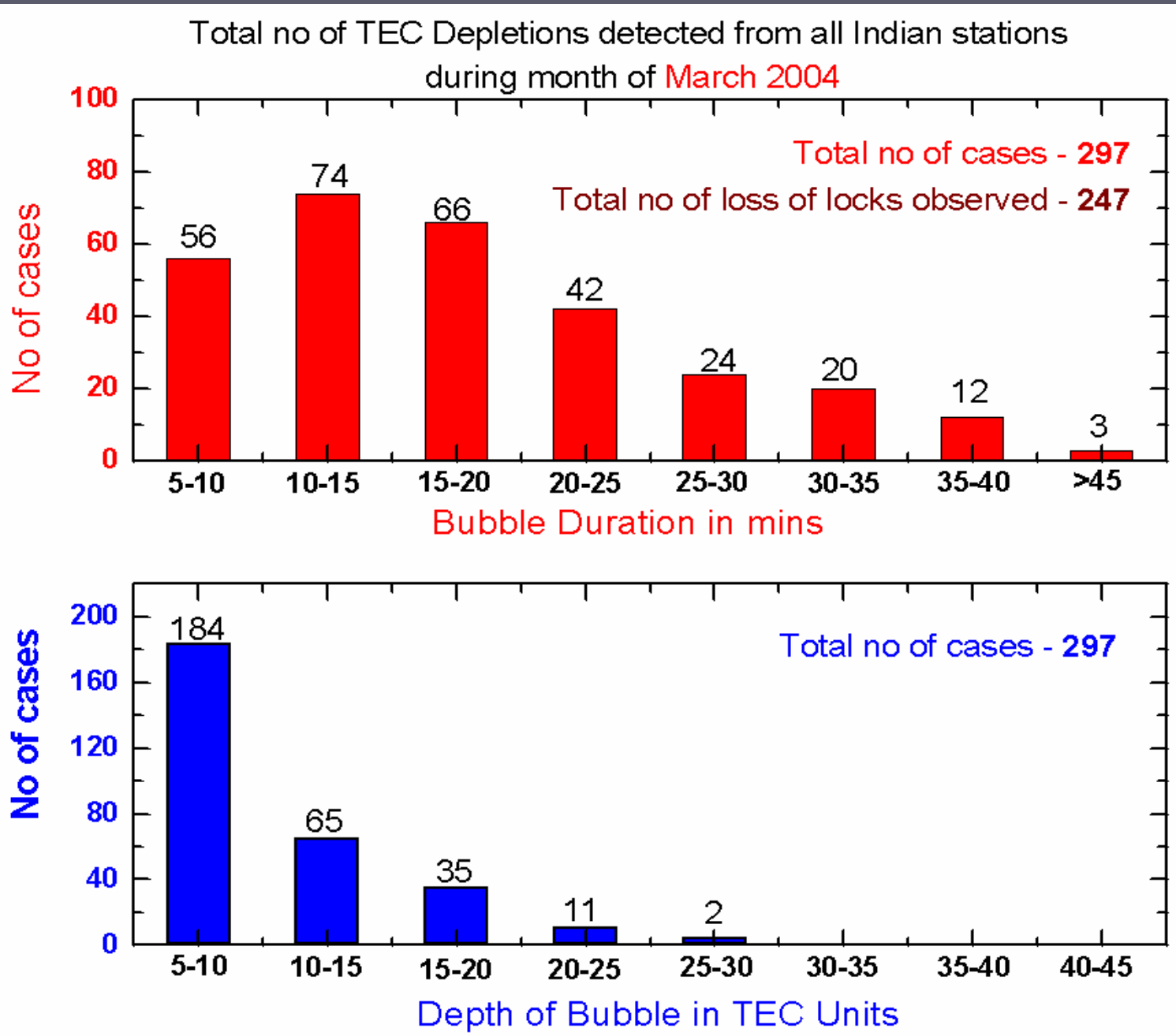
Total no of TEC Depletions detected from all Indian stations
during month of March 2004
Total no of cases - 297
Total no of loss of locks observed - 247
No of cases
100
80
60
40
20
0
56
74
66
42
24
20
12
3
5-10
10-15
15-20
20-25
25-30
30-35
35-40
>45
Bubble Duration in mins
Total no of cases - 297
No of cases
200
160
120
80
40
0
184
65
35
11
2
5-10
10-15
15-20
20-25
25-30
30-35
35-40
40-45
Depth of Bubble in TEC Units

Summary

Scintillations and Depletions

- The scintillation activity at the L-band frequency of 1.5 GHz is mostly confined to the pre-midnight hours, with practically no significant scintillation activity during the post midnight and summer months of this Low Sunspot Activity years of 2004 - 2006.
- The scintillation activity is significant in the equinox months of March, April, September & October during this LSSA period.
- Scintillations > 10dB (S4 index ≈ 0.45) occur more frequently around the regions of EIA (confining to 15 to 25^{o}N geog. lat)
- These scintillations are often accompanied by the TEC depletions (bubbles); sometimes resulting in the loss of lock of the GPS receiver phase.

Continued….

- The occurrence of these bubbles is also found to be maximum during the equinox months peaking around the equatorial ionization anomaly region of 15^{o} to 25^{o} geographic latitudes.
- The most probable bubble durations vary from 10 to 30 minutes and their amplitudes vary from 5 to 20 TEC units, which correspond to a range error of about 1 to 3.5 metres in the GPS navigation.
- Of concern to all users is that the increase in solar activity over the next four years, which will stress the GPS system and applications developed. Specifically, there may be disruptions of the signal during precision approaches of aircraft landing (GPS augmentation systems)
- It is question, whether the system will be more susceptible to unintentional and intentional (jamming) interference during that period (high solar activity). These issues emphasizes the risk to aviation of relying on a single navigation aid using GPS.

Thank you

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