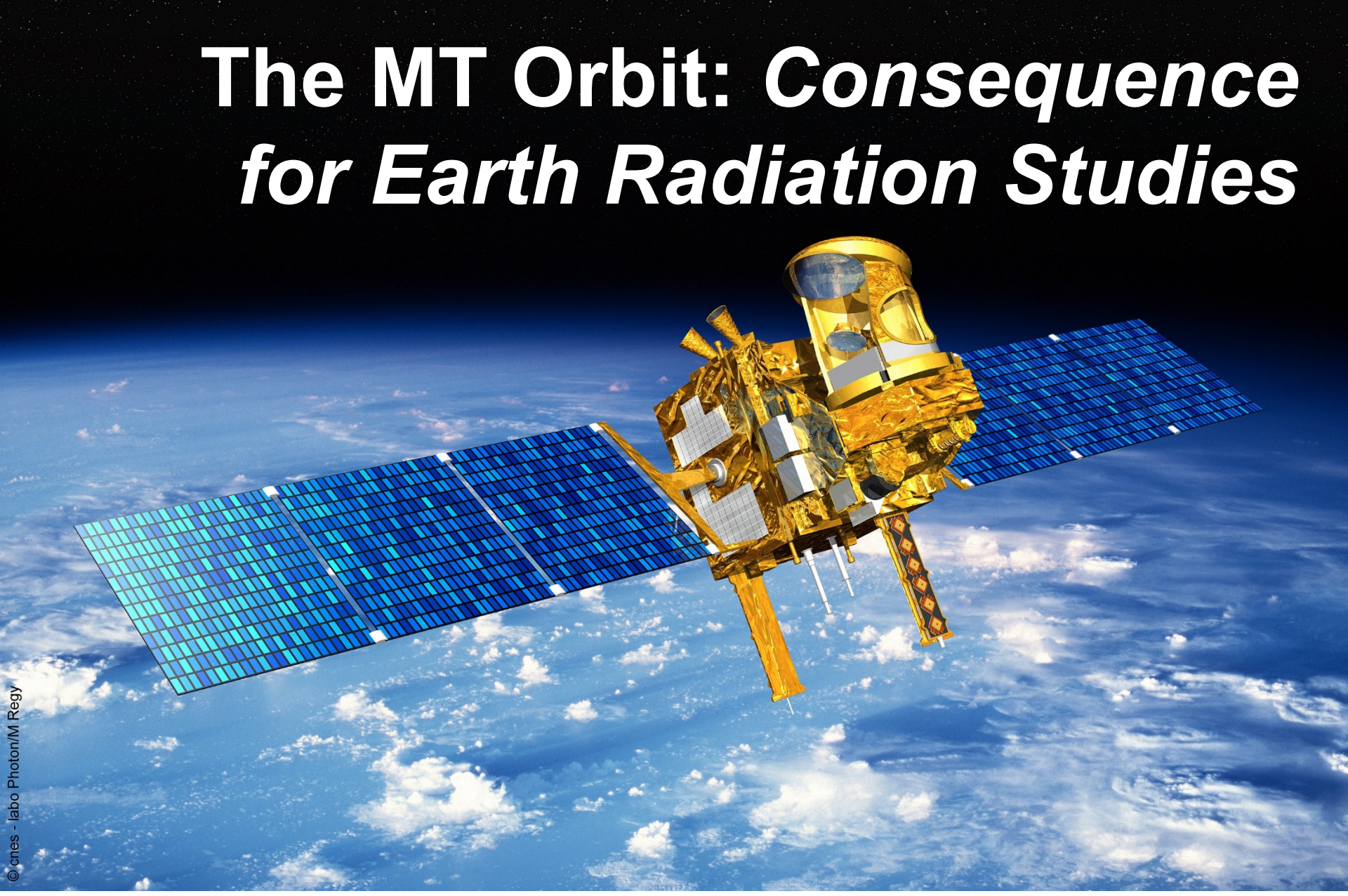
The MT Orbit: *Consequence for Earth Radiation Studies*



Earth Radiation Budget Workshop 2014 - Toulouse, France

Tuesday, October 7

Michel Capderou

LMD / IPSL, Ecole Polytechnique, Palaiseau, France

Megha-Tropiques
Orbit - ref.: Earth

Altitude = 865.5 km a = 7243.677 km

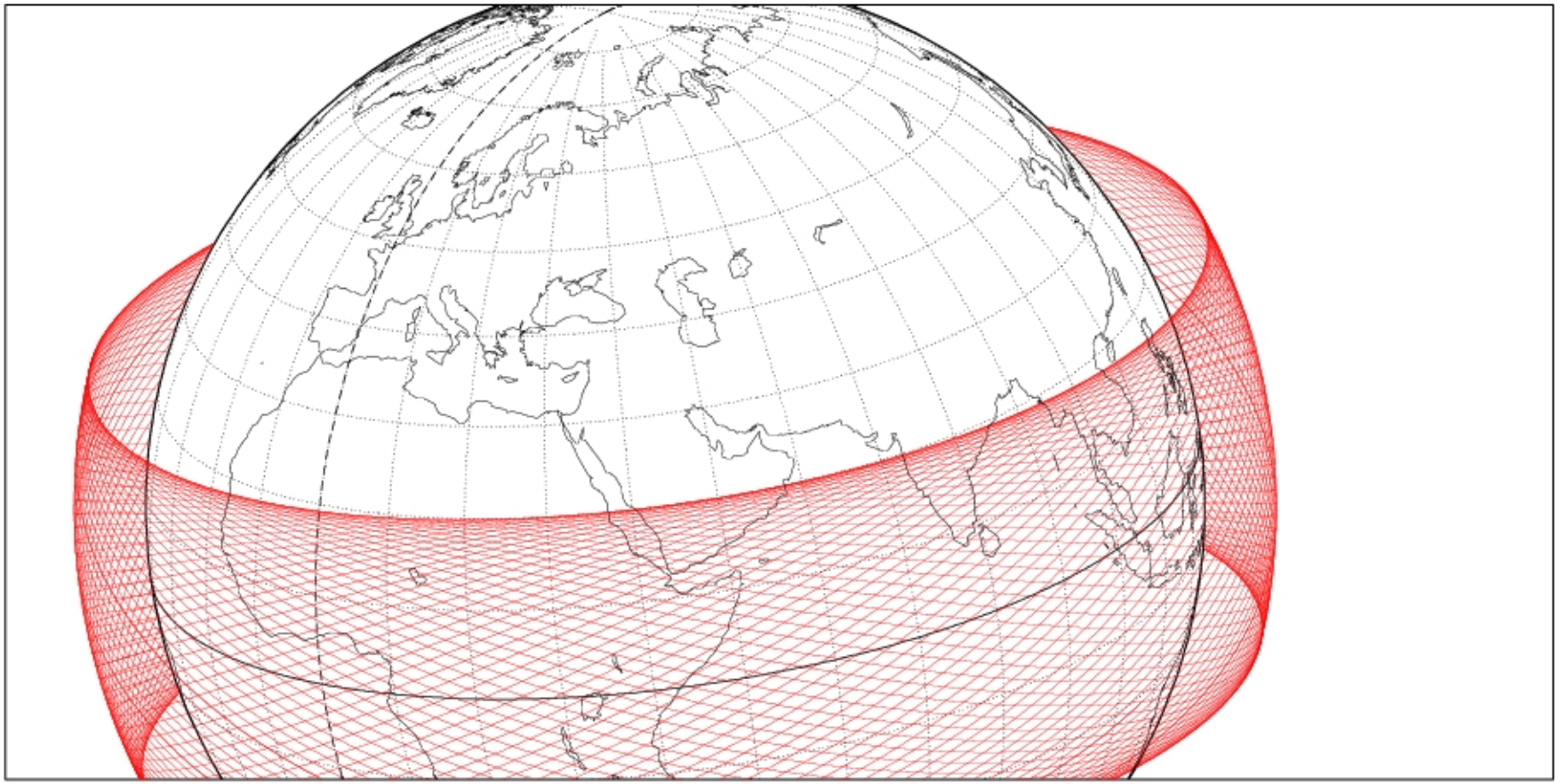
Inclination = 20.00 °

Recurrence = [14; -1; 7] 97

Period = 101.93 min * rev/day =14.13

>>>> Time span shown: 7.00 days

Equat. orbital shift = 2892.0 km (26.0 °)



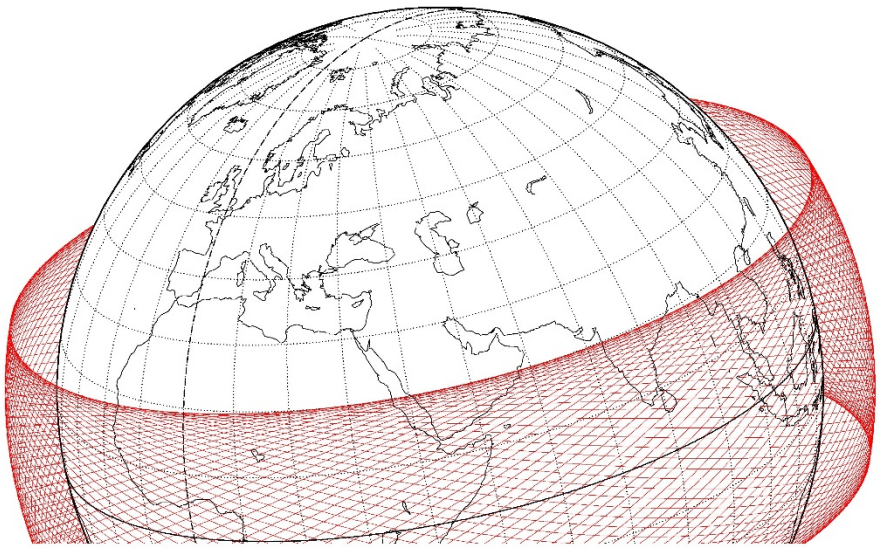
Projection: Orthographic PC: 20.0 ° N; 45.0 °E /ZC: 30.0 ° N; 60.0 ° E Asc. node: -180.00 ° [00:00 LMT]

Property: none Aspect: Oblique

⊕ T.:Azimuthal - Graticule: 10° {4.2}[-90.0/ +70.0/ +45.0] [+8] EIGEN-C3

Ιξιων
MC ★ LMD
Ατλας

MT : A unique example for LEO satellites, with *i* = 20°



***i* = 20° MT**

i = 35° TRMM

i = 40° GPM – LIO

i = 65° GPM – core

i = 66° Jason

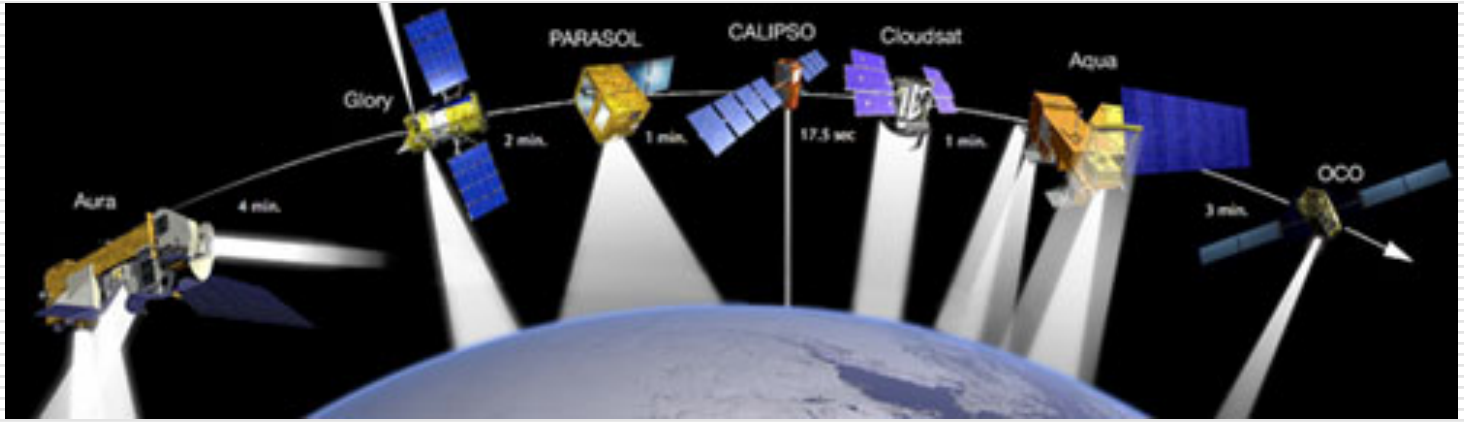
i* = 98° *Sun-synchronous

MT Orbit

Satellite Altitude : h = 866 km.

Inclination : i = 20°

Period: T = 102 minutes (14.1 Rev./day)



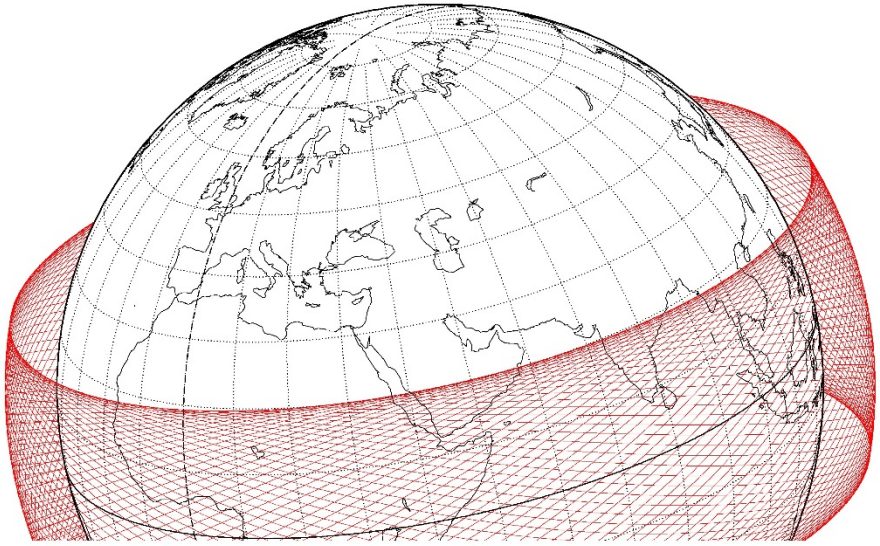
GPM-core …….. h = 398 km
TRMM …….. h = 350 km then 402 km

Terra, Aqua (and A-Train) …… h = 700 km
Suomi-NPP ……..…. h = 824 km

The Orbit of ***Megha-Tropiques***: Consequences for the Sampling and for the Earth Radiation Budget Studies.

- 1 – Precession of the Orbital Plane (Cycle w.r.t. the Sun)
- 2 – Sun-Target-Satellite Geometry for Angular Distribution Models.
- 3 – Sampling for the Tropical Zone
- 4 – MT and Terra Rendez-vous
- 5 – Orbit Maintenance

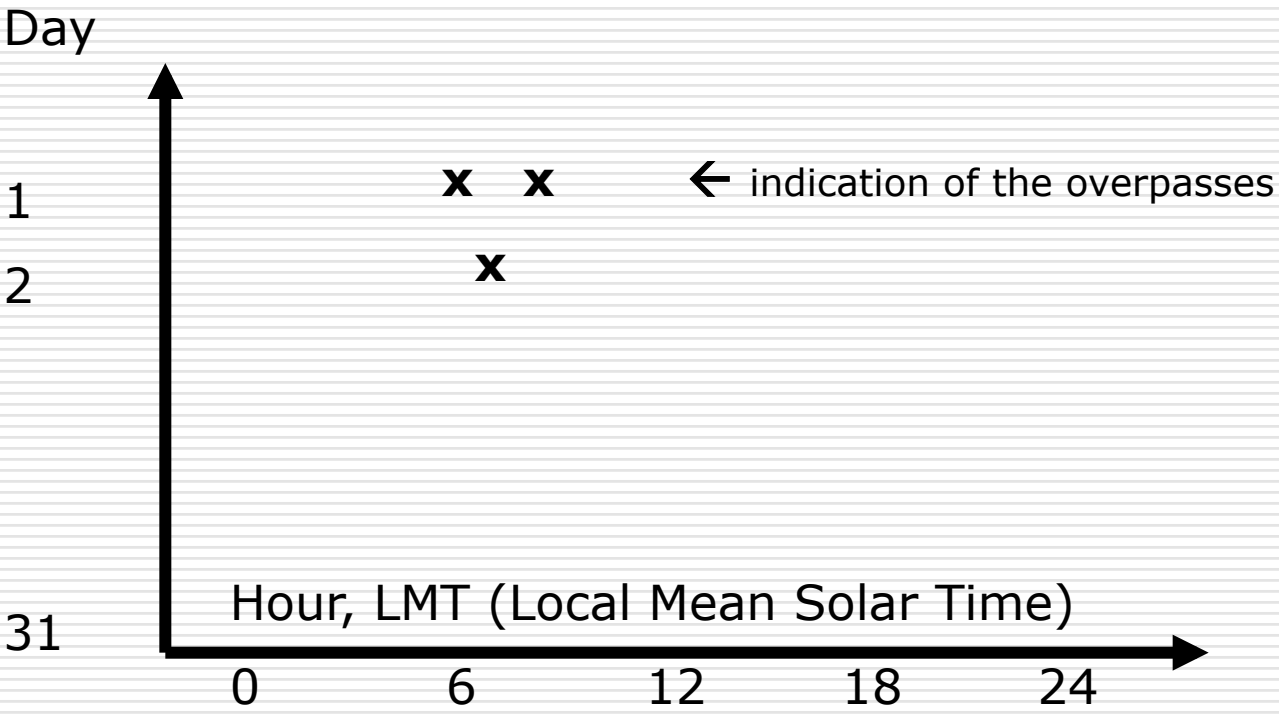
Cycle w. r. t. the Sun (Precession of the orbital plane)

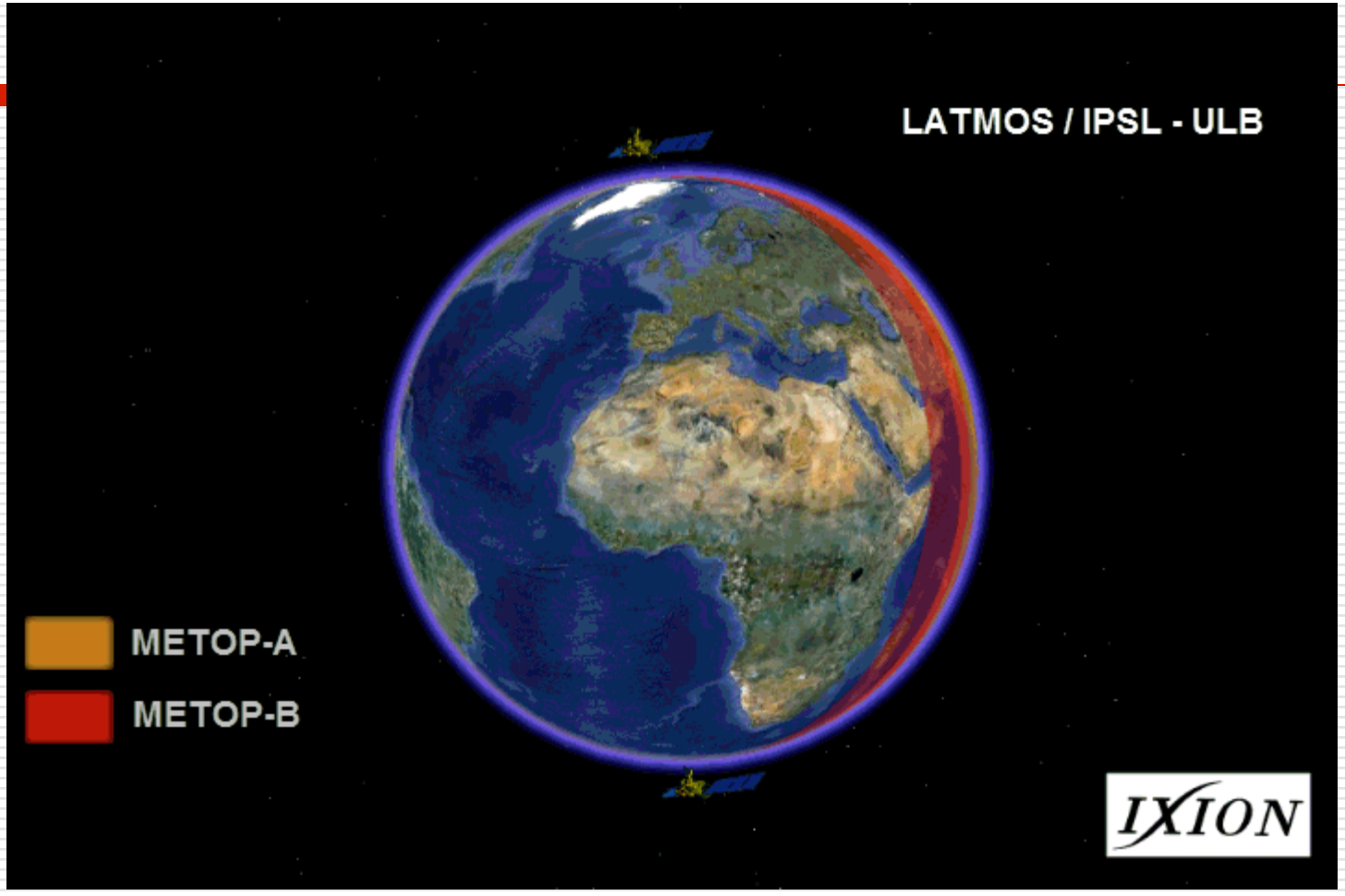


1

Monthly table

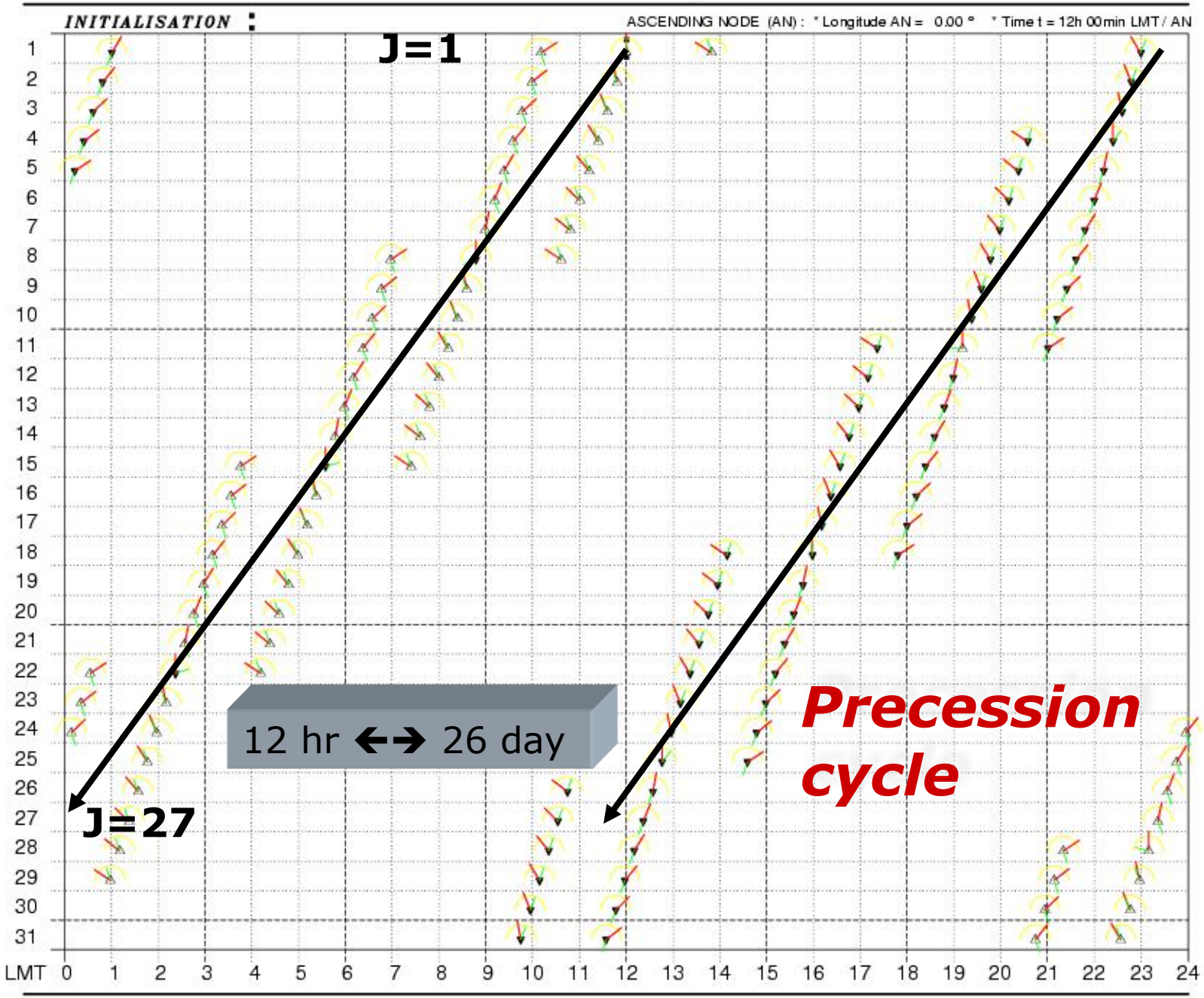
For a given location




LATMOS / IPSL - ULB
METOP-A
METOP-B
IXION

Recurrence cycle = 7 days [14; -1; 7] 97
Precession cycle= 51 days (Cs= -51.3)
***

Megha-Trop. / ScaRaB



0 °

MONTHLY TABLE

OVERPASSES (n = 136)
OF SATELLITE S [G
FOR POINT P
- Latitude : 0.0 °
- Longitude : 0.0 °
For P: UTC = LMT + 00h (

FIELD OF VIEW : 97

(1) (2) P-S DIRECTIO
△ ASC ▼

Right-handed system

- Zenith angle (in the plane orthogonal to the track).

- Azimuth (in the local horizontal plane) with respect to the North.

ORBIT a = 7243.
Altitude = 865.6 km
Inclination = 20.00 °
Equatorial shift= 2892.0 km
Period = 101.93 min
Mean mot. = 14.13 rev/day

SCANNING
Half-swath = 48.9 °
Maximal zenith angle = 58.9
H.-swath (ground) = 1108.3 k
Equatorial overlap = 2.08
Max. attained latit. = 30.0 °

Ιξιων
MC ★ LMD

Prescession Cycle

The time interval needed for
the hour angle of ascending node
to vary by 24 hr.

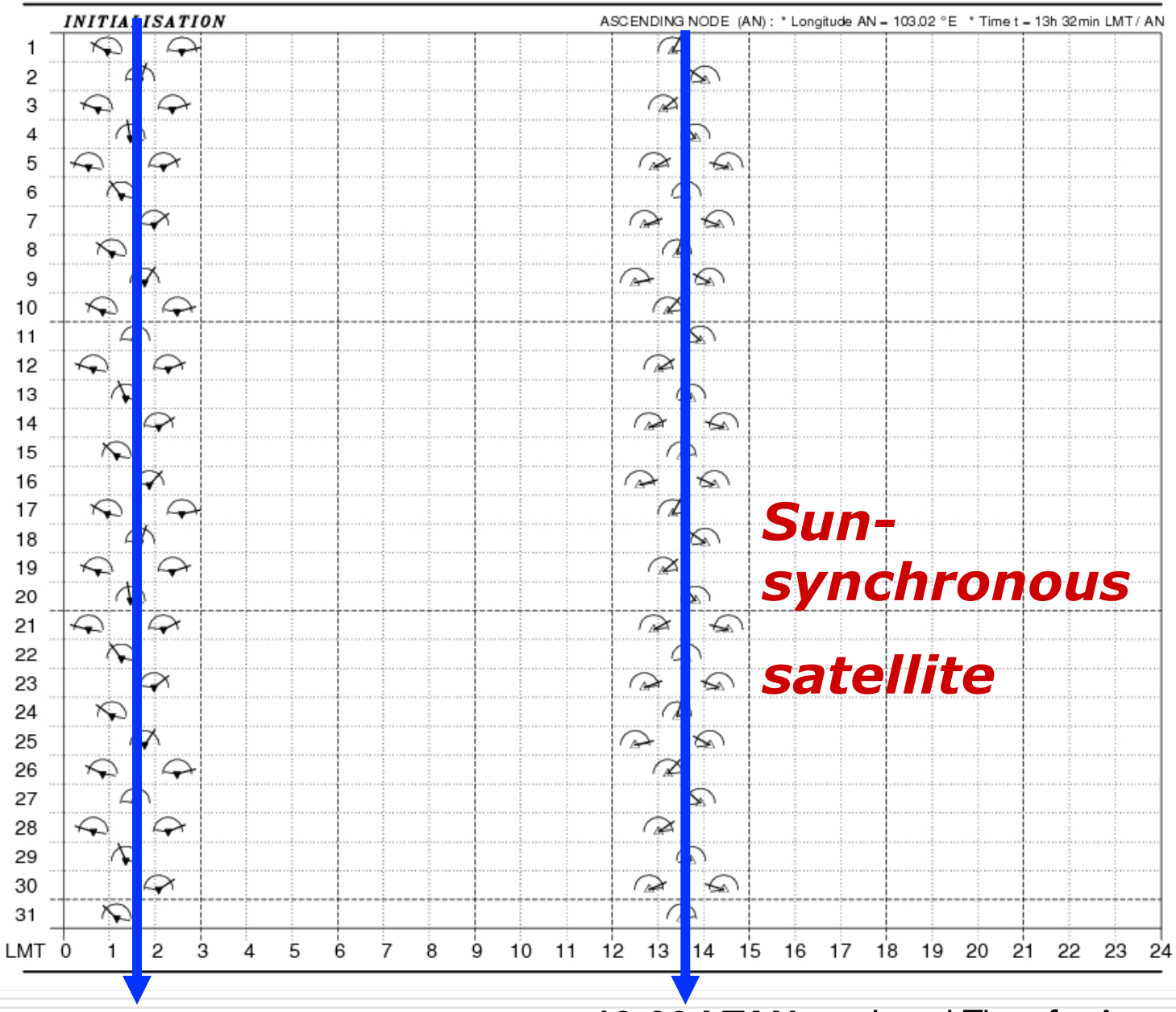
- For Megha-Tropiques,
the precession cycle is short : ***51 days***

Recurrence cycle = 16 days [15; -7; 16] 233
Precession cycle: infinity (SUN-S.)
***

Aqua / CERES

0 °

MONTHLY TABLE



OVERPASSES (n = 81)
OF SATELLITE S [EGM96]
FOR POINT P
- Latitude : 0.0 °
- Longitude : 75.0 ° E
For P: UTC = LMT - 05h 00m

FIELD OF VIEW : 123.6 °

(1) (2) P-S DIRECTION
△ ASC ▼ DES

Right-handed system
- Zenith angle (in the plane orthogonal to the track). (1)
- Azimuth (in the local horizontal plane) with respect to the North. (2)

ORBIT a = 7077.736 km
Altitude = 699.6 km
Incl. / Sun-s. = 98.21 °
Equatorial shift= 2751.9 km
Period = 98.88 min
Mean mot. = 14.56 rev/day

SCANNING
Half-swath = 61.8 °
Maximal zenith angle = 78.0 °
H.-swath (ground) = 1801.2 km
Equatorial overlap = 1.336
Max. attained latit. = 90.0 °
Latit. overlap:82.0° <--> 90.0°

Ixiwn
MC ★ LMD

13:30 LTAN Local Time for Ascending Node

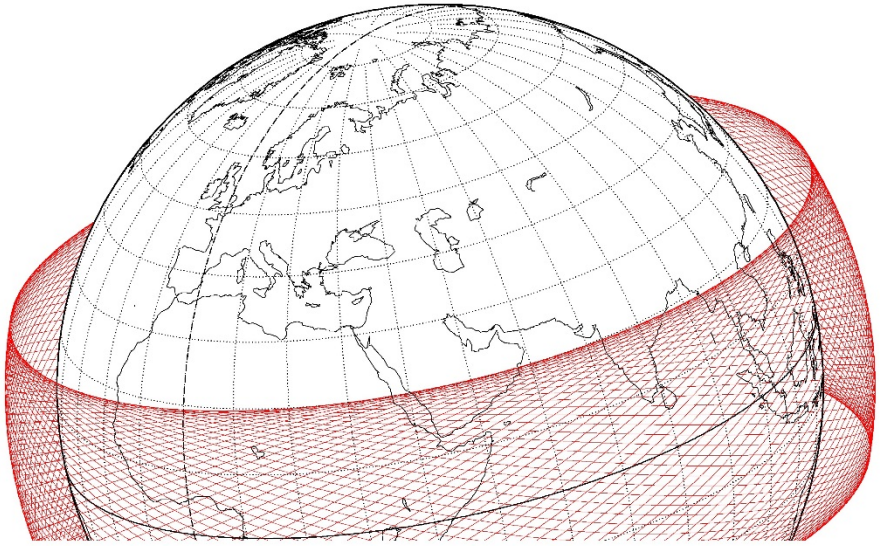
Cycles w. r. t. the Sun

***LTAN**: Local Solar Mean Time of the Ascending Node*
= Equatorial Crossing Time

- Megha-Tropiques …. Cycle=51 d i.e. -28 minutes per day
- GPM-core ……. Cycle=82 d i.e. -18 minutes per day
- Sun-Synchronous S. Cycle:infinity i.e. 0 minute per day

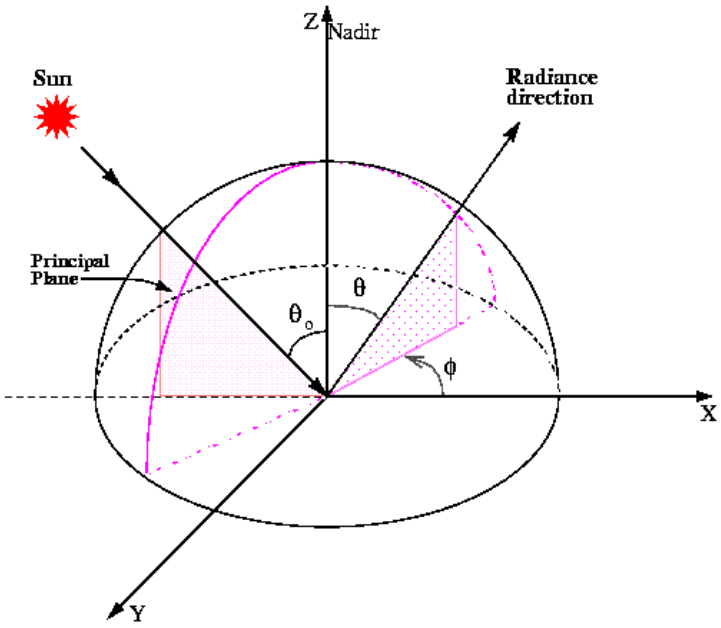
Sun-Target-Satellite Geometry for Angular Distribution Models

(Earth Radiation Budget Studies)



2

Sun-Target-Satellite Geometry



θ_o: Solar zenith angle.

θ: Zenith angle of the radiance. Range: 0-180.; 0 for straight-up; 90 for horizon; and 180 for straight-down.

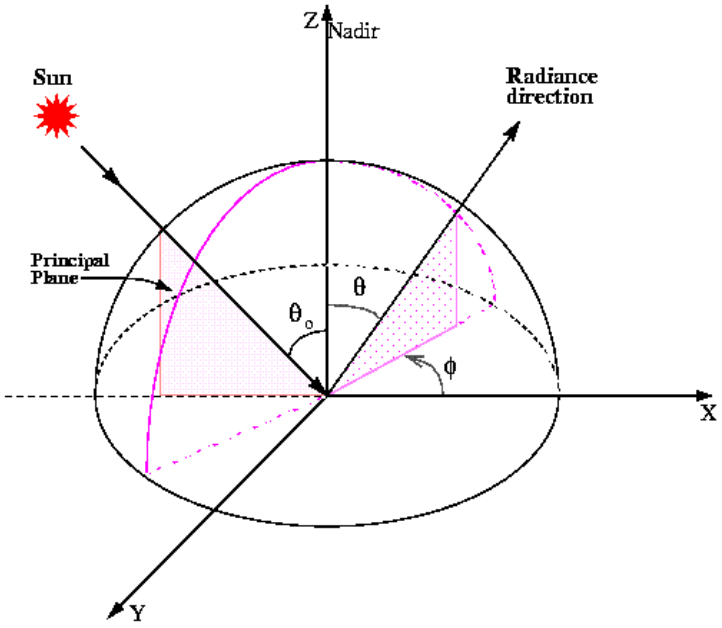
ϕ: Relative azimuth angle of radiance. Range: 0-360.; 0 as forward scattering; 180 as back scattering.

SZA: Solar Zenith Angle
VZA: Viewing Zenith Angle
RAA: Relative Azimuth Angle

Discretization of the S-T-S Geometry with Angular Bins

Bins of 10 degrees for SZA and VZA
Bins of 20 degress for RA

SZA: 0° to 90° ➔ Bin I : 1 to 9
VZA: 0° to 90° ➔ Bin J : 1 to 9
RAA: 0 to 180° ➔ Bin K : 1 to 9



Example

SZA: Solar Zenith Angle
VZA: Viewing Zenith Angle
RAA: Relative Azimuth Angle

In this graph:

θ_o (or SZA) = 48° ➔ Bin I = 5

θ (or VZA) = 32° ➔ Bin J = 4

ϕ (or RAA) = 38° ➔ Bin K = 2

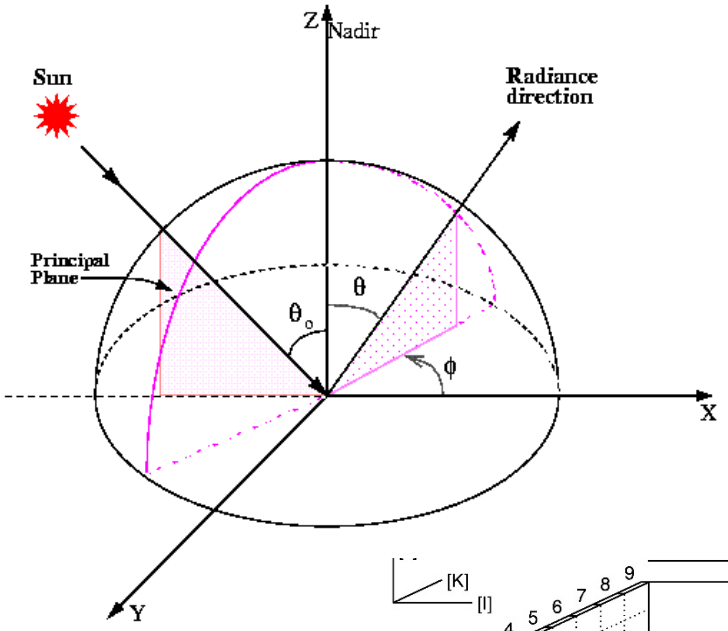
(5, 4, 2)

Discretization of the S-T-S Geometry with Angular Bins

SZA : Bin I = 1 (0° to 10°), I = 2 (10° to 20)°, …. I = 9 (80° to 90°)

VZA : Bin J = 1 (0° to 10°), J = 2 (10° to 20)°, …. J = 9 (80° to 90°)

RAA : Bin K = 1 (0° to 20°), K = 2 (20° to 40)°, …. K = 9 (160° to 180°)

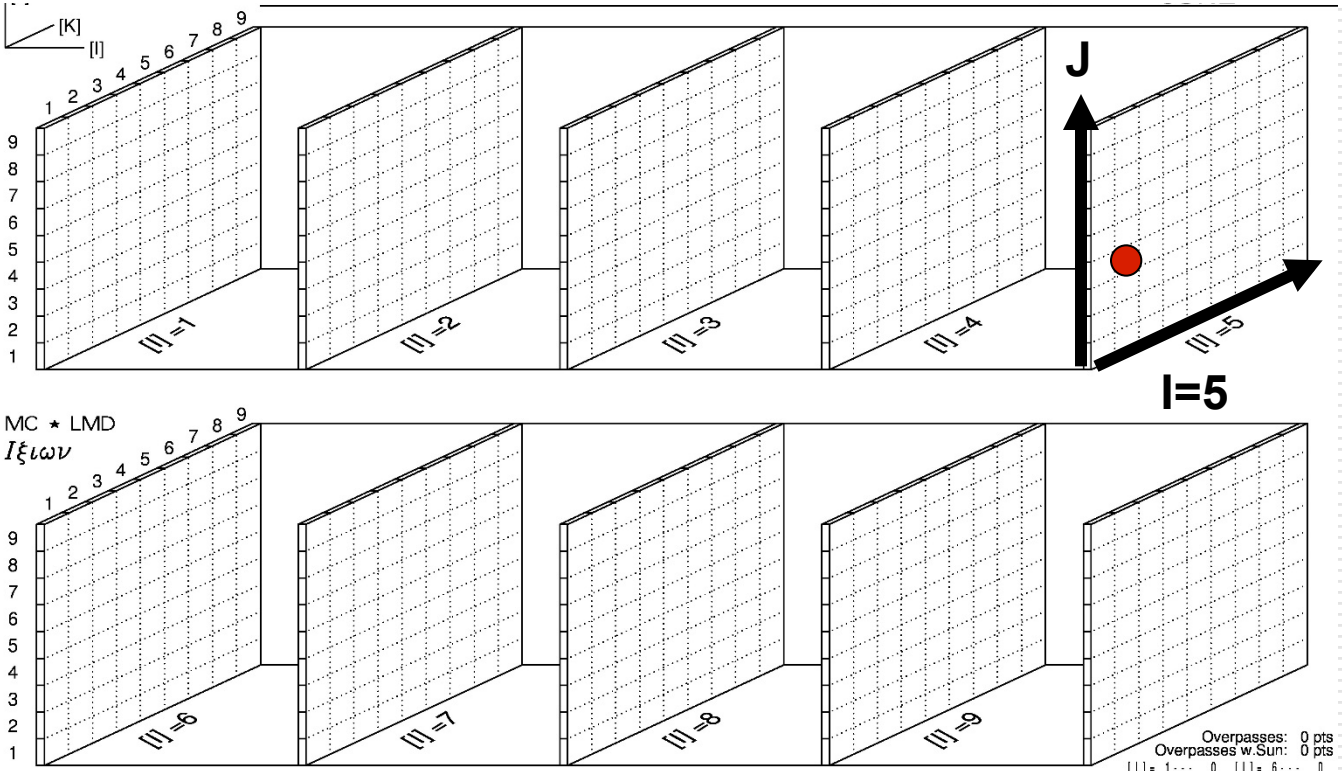

Z
Nadir
Sun
Radiance
direction
Principal
Plane
θ
θ
o
ϕ
X
Y

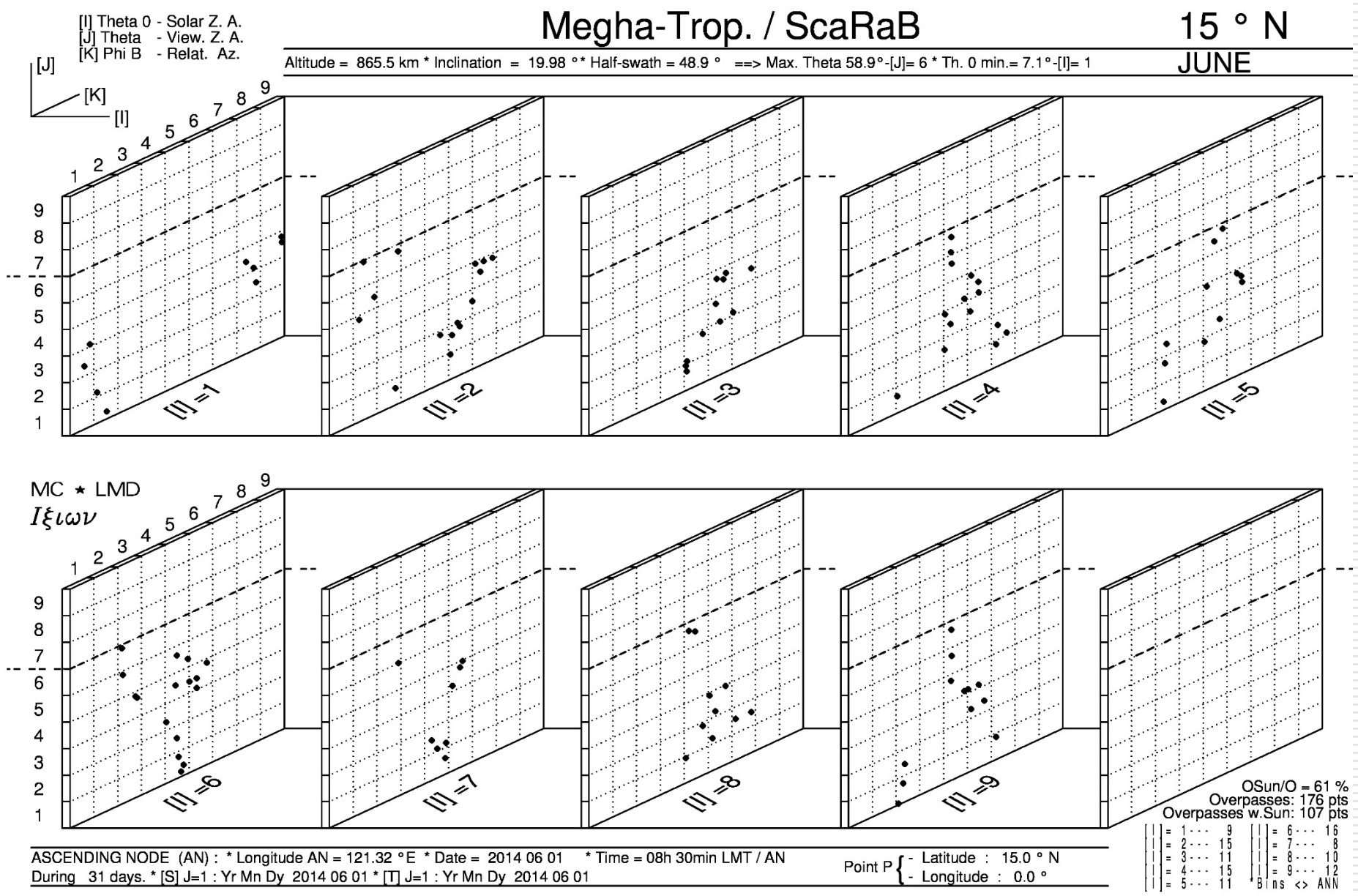
(5, 4, 2)

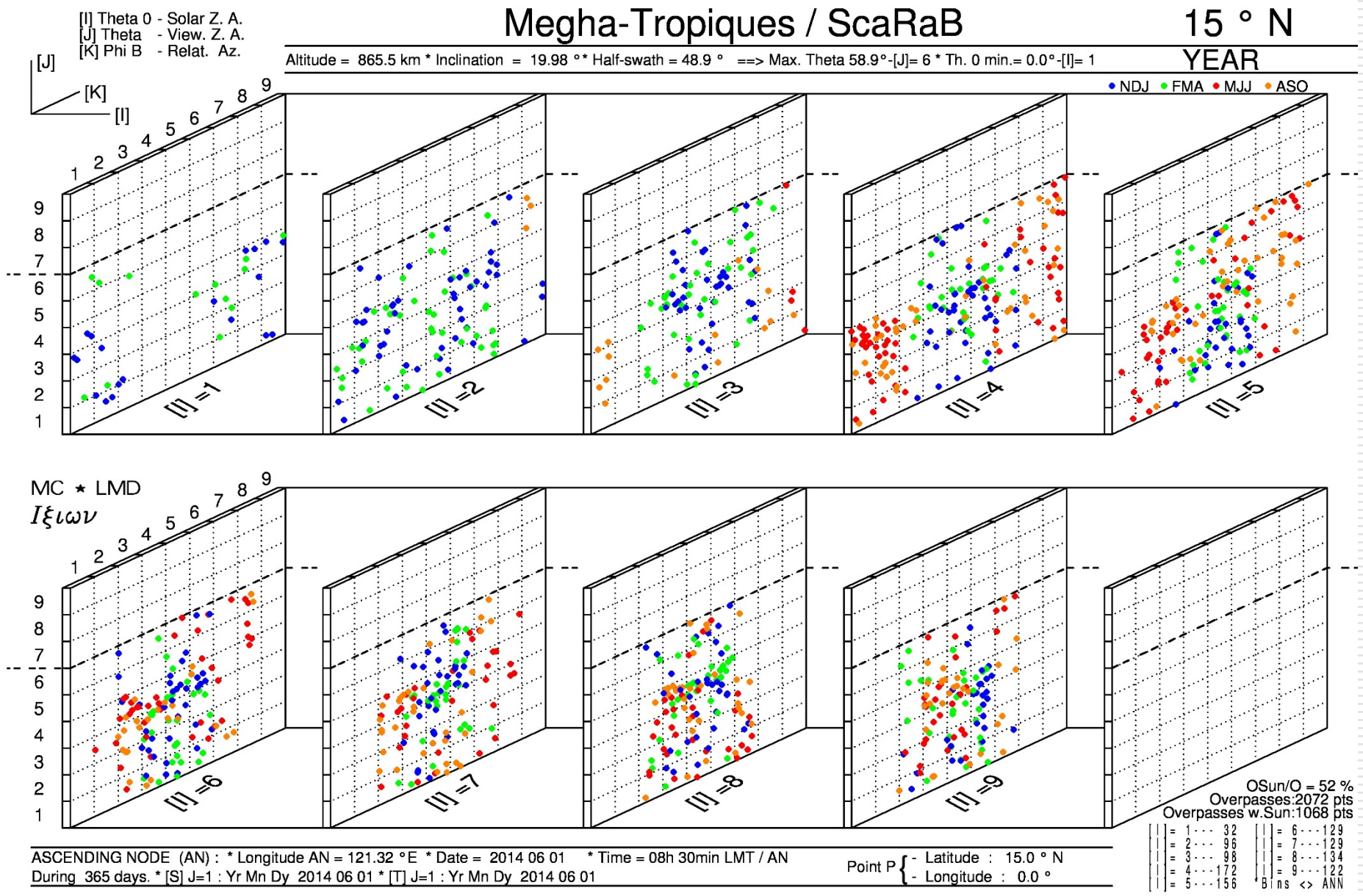
I = 5

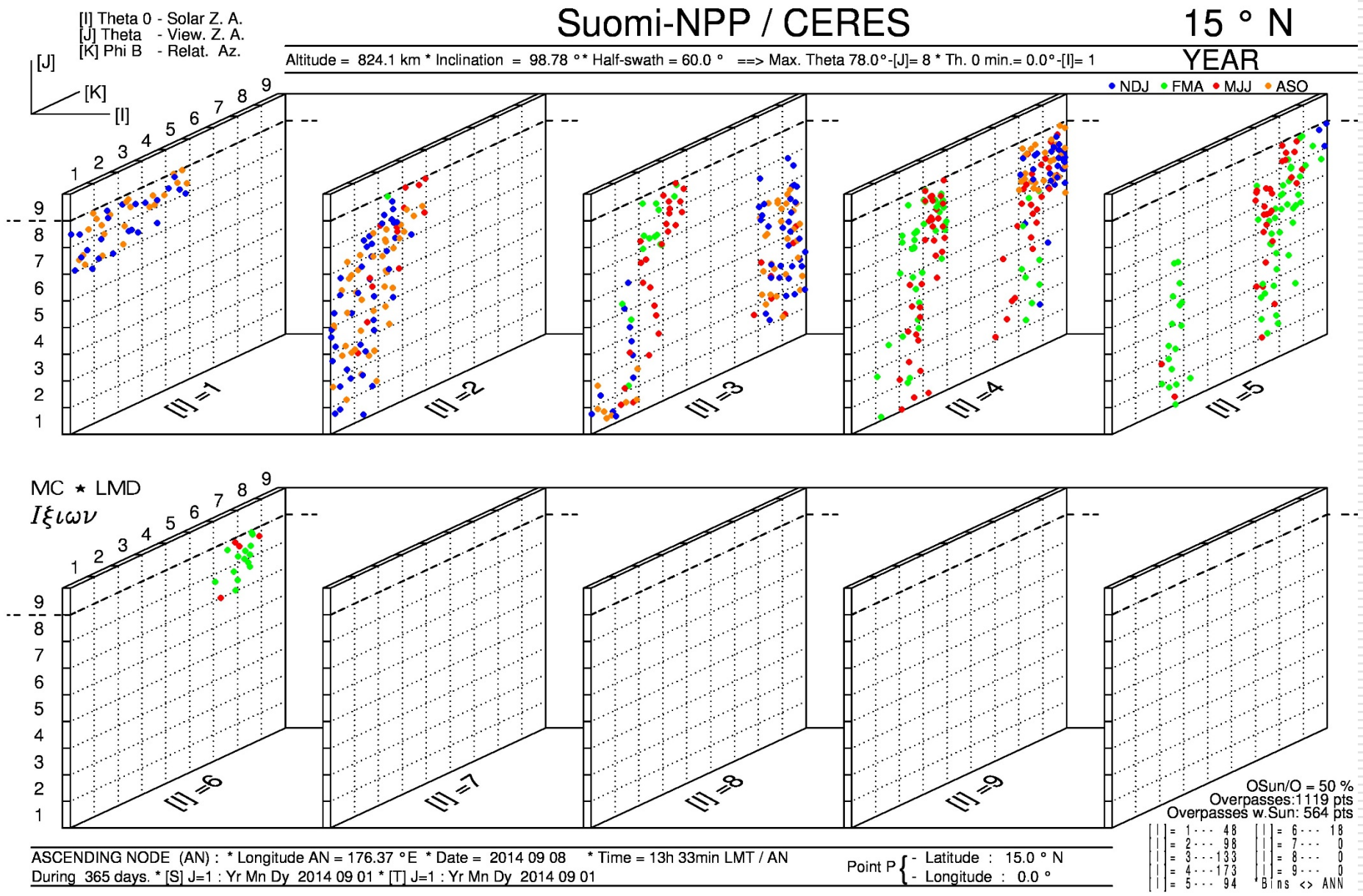
J = 4

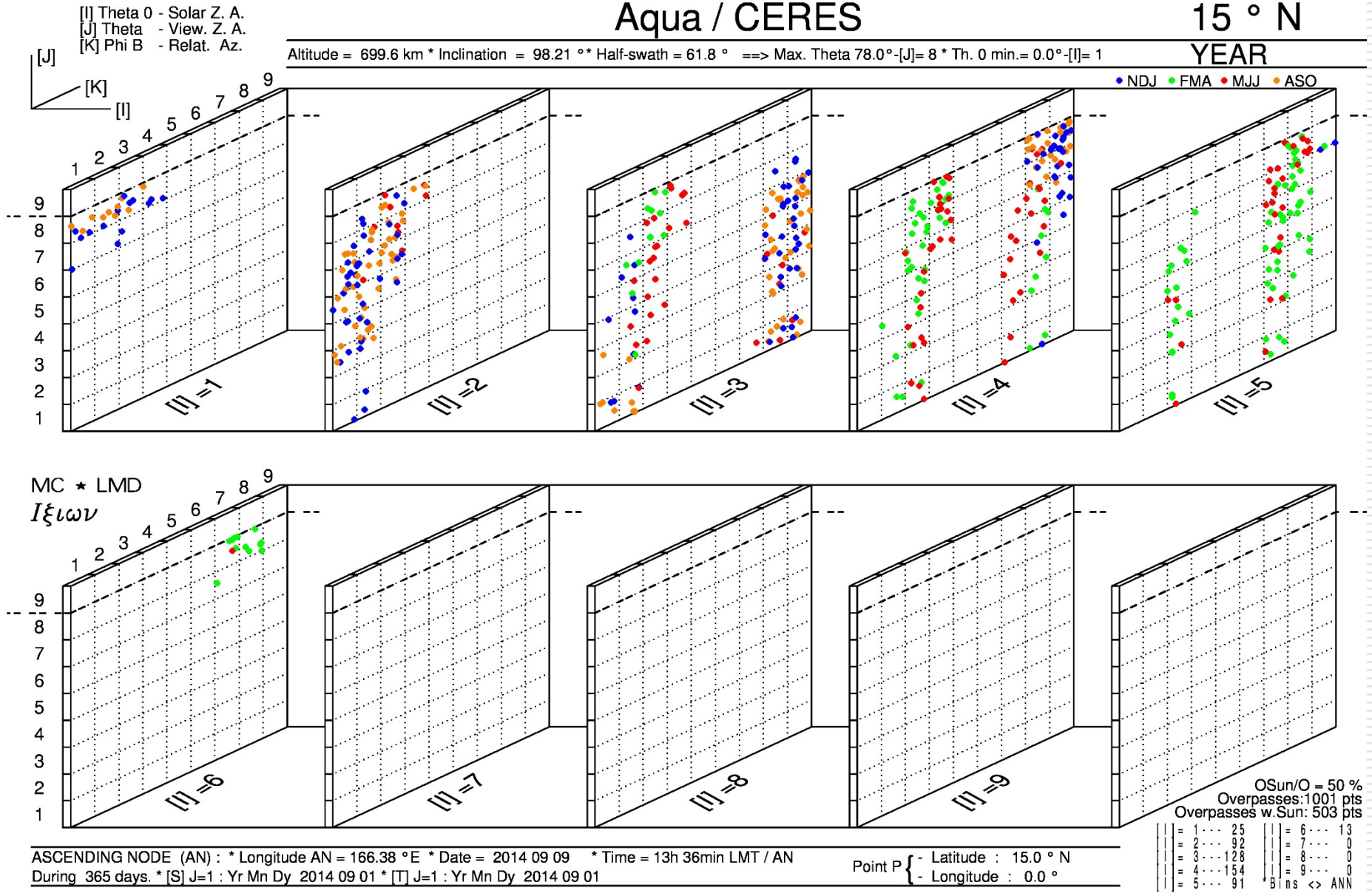
K = 2

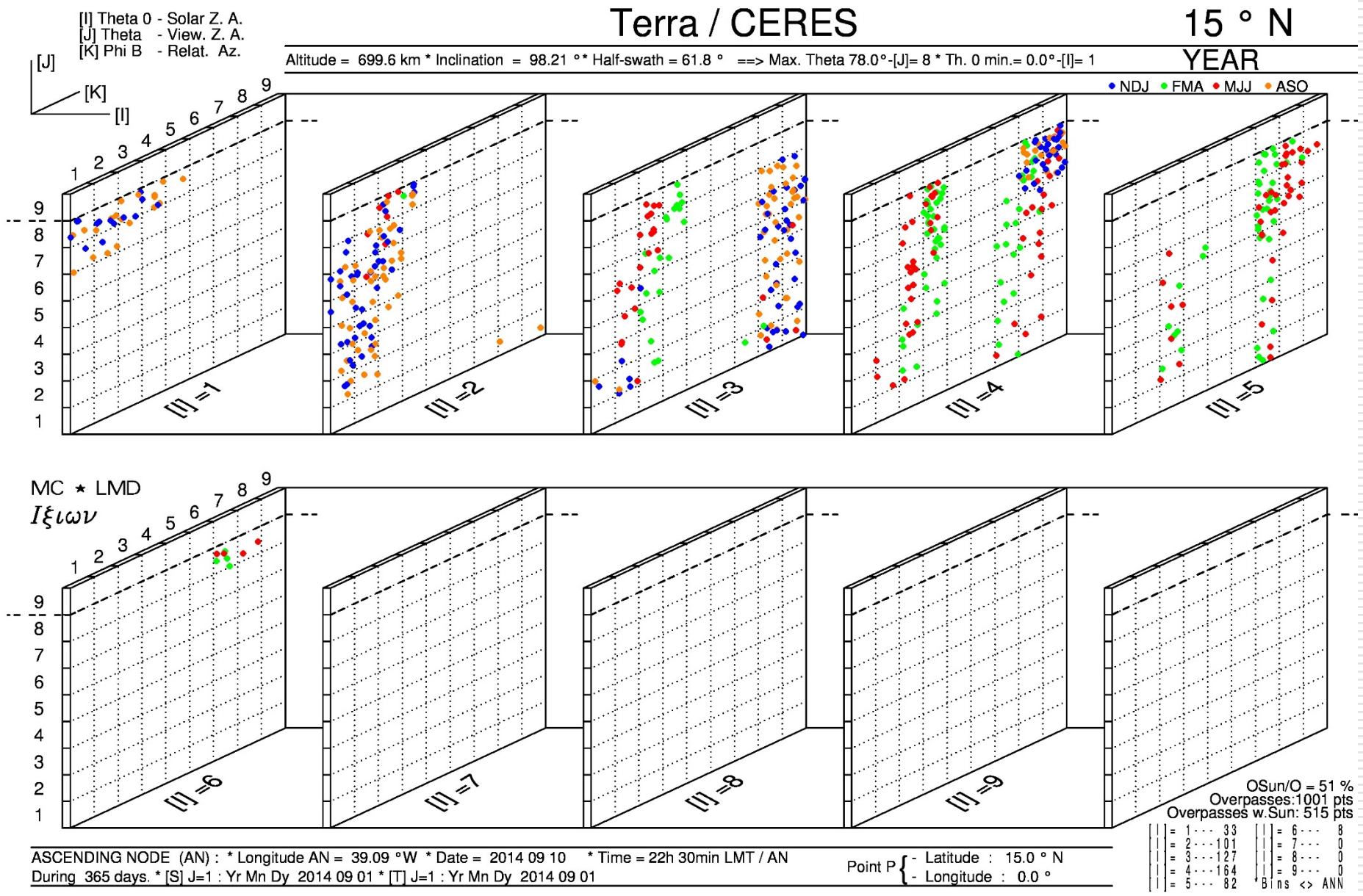

[K]
[I]
J
K
I=5
[I] =1
[I] =2
[I] =3
[I] =4
[I] =5
[I] =6
[I] =7
[I] =8
[I] =9
MC ★ LMD
Ιξιων
Overpasses: 0 pts
Overpasses w.Sun: 0 pts

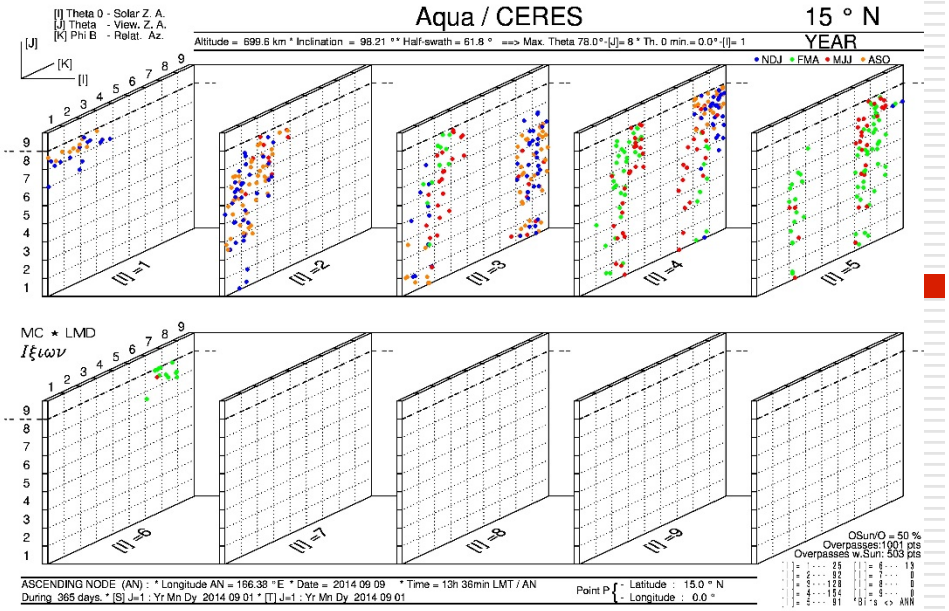

[I] Theta 0 - Solar Z. A.
[J] Theta - View. Z. A.
[K] Phi B - Relat. Az.
Megha-Trop. / ScaRaB
15 ° N
Altitude = 865.5 km * Inclination = 19.98 ° * Half-swath = 48.9 ° ==> Max. Theta 58.9°-[J]= 6 * Th. 0 min.= 7.1°-[I]= 1
JUNE
[J]
[K]
[I]
[I] =1
[I] =2
[I] =3
[I] =4
[I] =5
MC ★ LMD
Ιξιων
[I] =6
[I] =7
[I] =8
[I] =9
OSun/O = 61 %
Overpasses: 176 pts
Overpasses w.Sun: 107 pts
= 1 9
= 2 15
= 3 11
= 4 15
= 5 11
= 6 16
= 7 8
= 8 10
= 9 12
Bins <> ANN
ASCENDING NODE (AN) : * Longitude AN = 121.32 °E * Date = 2014 06 01 * Time = 08h 30min LMT / AN
During 31 days. * [S] J=1 : Yr Mn Dy 2014 06 01 * [T] J=1 : Yr Mn Dy 2014 06 01
Point P - Latitude : 15.0 ° N
- Longitude : 0.0 °

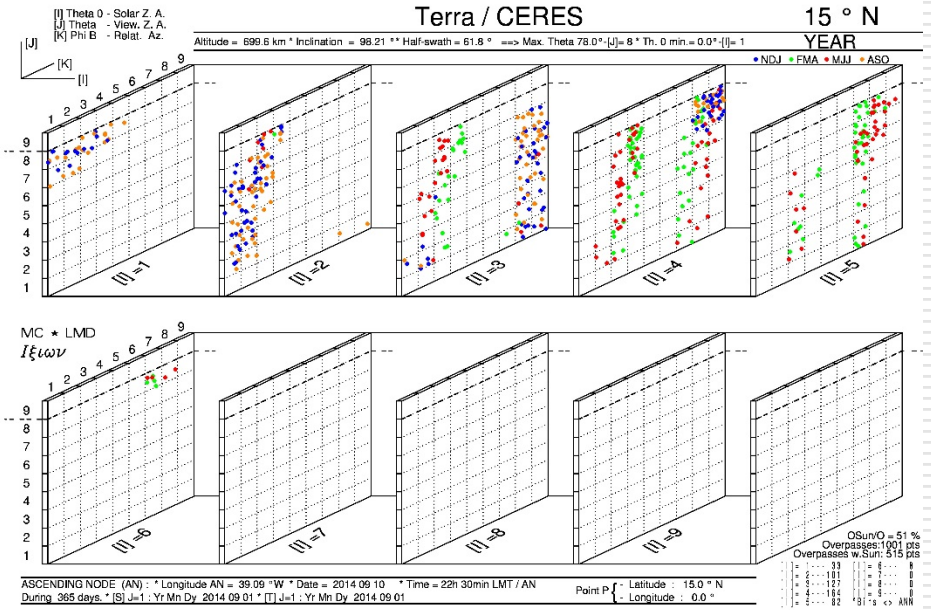

[I] Theta 0 - Solar Z. A.
[J] Theta - View. Z. A.
[K] Phi B - Relat. Az.
Megha-Tropiques / ScaRaB
15 ° N
Altitude = 865.5 km * Inclination = 19.98 ° * Half-swath = 48.9 ° ==> Max. Theta 58.9°-[J]= 6 * Th. 0 min.= 0.0°-[I]= 1
YEAR
NDJ FMA MJJ ASO
[J]
[K]
[I]
[I] =1
[I] =2
[I] =3
[I] =4
[I] =5
[I] =6
[I] =7
[I] =8
[I] =9
MC ★ LMD
Ιξιων
OSun/O = 52 %
Overpasses:2072 pts
Overpasses w.Sun:1068 pts
ASCENDING NODE (AN) : * Longitude AN = 121.32 °E * Date = 2014 06 01 * Time = 08h 30min LMT / AN
During 365 days. * [S] J=1 : Yr Mn Dy 2014 06 01 * [T] J=1 : Yr Mn Dy 2014 06 01
Point P - Latitude : 15.0 ° N
- Longitude : 0.0 °
Bins <> ANN

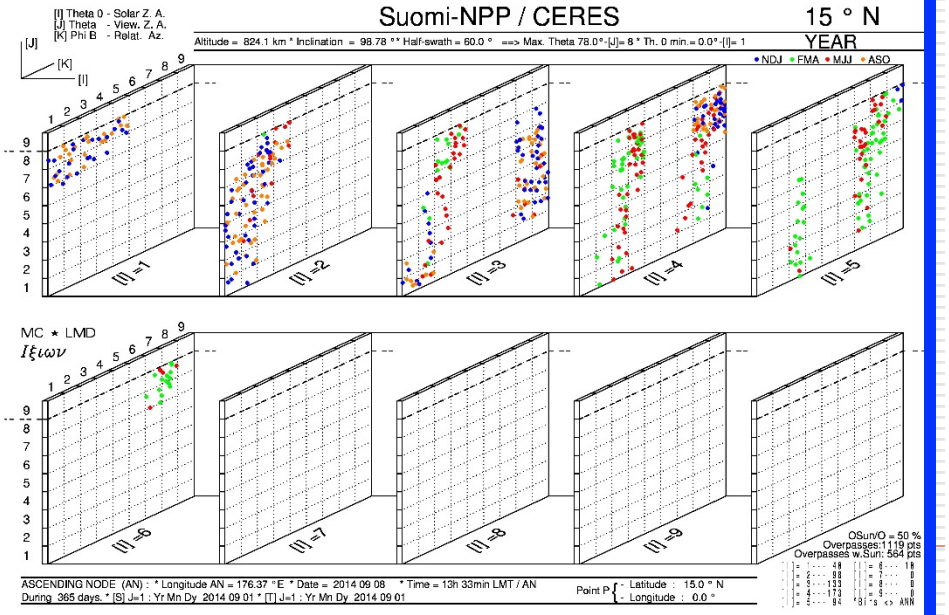

[I] Theta 0 - Solar Z. A.
[J] Theta - View. Z. A.
[K] Phi B - Relat. Az.
Suomi-NPP / CERES
15 ° N
Altitude = 824.1 km * Inclination = 98.78 ° * Half-swath = 60.0 ° ==> Max. Theta 78.0°-[J]= 8 * Th. 0 min.= 0.0°-[I]= 1
YEAR
NDJ FMA MJJ ASO
[J]
[K]
[I]
[I] =1
[I] =2
[I] =3
[I] =4
[I] =5
MC ★ LMD
Ιξιων
[I] =6
[I] =7
[I] =8
[I] =9
OSun/O = 50 %
Overpasses:1119 pts
Overpasses w.Sun: 564 pts
[I] = 1 --- 48
[I] = 2 --- 98
[I] = 3 --- 133
[I] = 4 --- 173
[I] = 5 --- 94
[I] = 6 --- 18
[I] = 7 --- 0
[I] = 8 --- 0
[I] = 9 --- 0
Bins <> ANN
ASCENDING NODE (AN) : * Longitude AN = 176.37 °E * Date = 2014 09 08 * Time = 13h 33min LMT / AN
During 365 days. * [S] J=1 : Yr Mn Dy 2014 09 01 * [T] J=1 : Yr Mn Dy 2014 09 01
Point P - Latitude : 15.0 ° N
- Longitude : 0.0 °

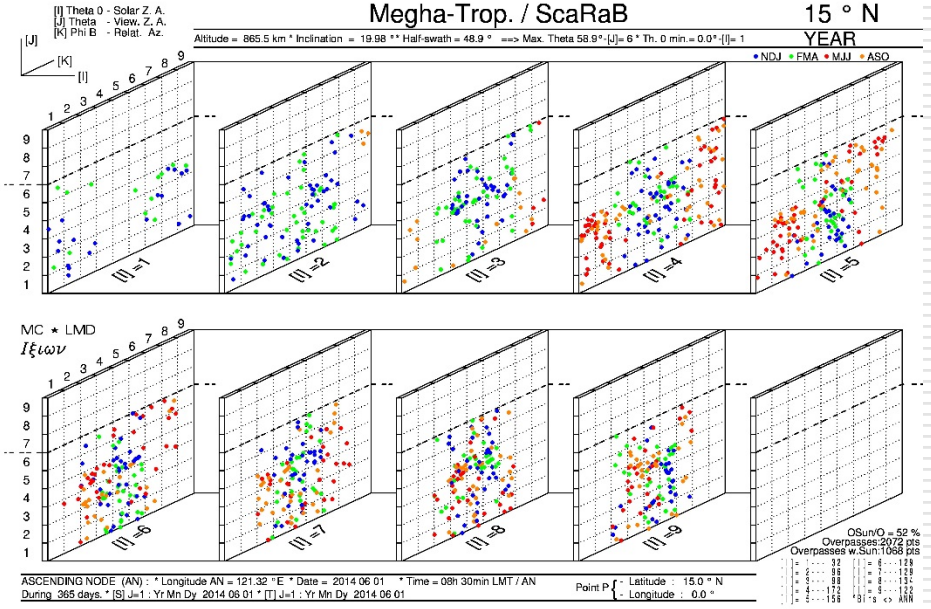

[I] Theta 0 - Solar Z. A.
[J] Theta - View. Z. A.
[K] Phi B - Relat. Az.
Aqua / CERES
15 ° N
Altitude = 699.6 km * Inclination = 98.21 °* Half-swath = 61.8 ° ==> Max. Theta 78.0°-[J]= 8 * Th. 0 min.= 0.0°-[I]= 1
YEAR
NDJ FMA MJJ ASO
[J]
[K]
[I]
[I] =1
[I] =2
[I] =3
[I] =4
[I] =5
[I] =6
[I] =7
[I] =8
[I] =9
MC ★ LMD
Ιξιων
OSun/O = 50 %
Overpasses:1001 pts
Overpasses w.Sun: 503 pts
1 25
2 92
3 128
4 154
5 91
6 13
7 0
8 0
9 0
Bins <> ANN
ASCENDING NODE (AN) : * Longitude AN = 166.38 °E * Date = 2014 09 09 * Time = 13h 36min LMT / AN
During 365 days. * [S] J=1 : Yr Mn Dy 2014 09 01 * [T] J=1 : Yr Mn Dy 2014 09 01
Point P - Latitude : 15.0 ° N
- Longitude : 0.0 °


[I] Theta 0 - Solar Z. A.
[J] Theta - View. Z. A.
[K] Phi B - Relat. Az.
Terra / CERES
15 ° N
Altitude = 699.6 km * Inclination = 98.21 °* Half-swath = 61.8 ° ==> Max. Theta 78.0°-[J]= 8 * Th. 0 min.= 0.0°-[I]= 1
YEAR
NDJ FMA MJJ ASO
[J]
[K]
[I]
[I] =1
[I] =2
[I] =3
[I] =4
[I] =5
[I] =6
[I] =7
[I] =8
[I] =9
MC ★ LMD
Ιξιων
OSun/O = 51 %
Overpasses:1001 pts
Overpasses w.Sun: 515 pts
1 --- 33
2 --- 101
3 --- 127
4 --- 164
5 --- 82
6 --- 8
7 --- 0
8 --- 0
9 --- 0
Bins <> ANN
ASCENDING NODE (AN) : * Longitude AN = 39.09 °W * Date = 2014 09 10 * Time = 22h 30min LMT / AN
During 365 days. * [S] J=1 : Yr Mn Dy 2014 09 01 * [T] J=1 : Yr Mn Dy 2014 09 01
Point P - Latitude : 15.0 ° N
- Longitude : 0.0 °

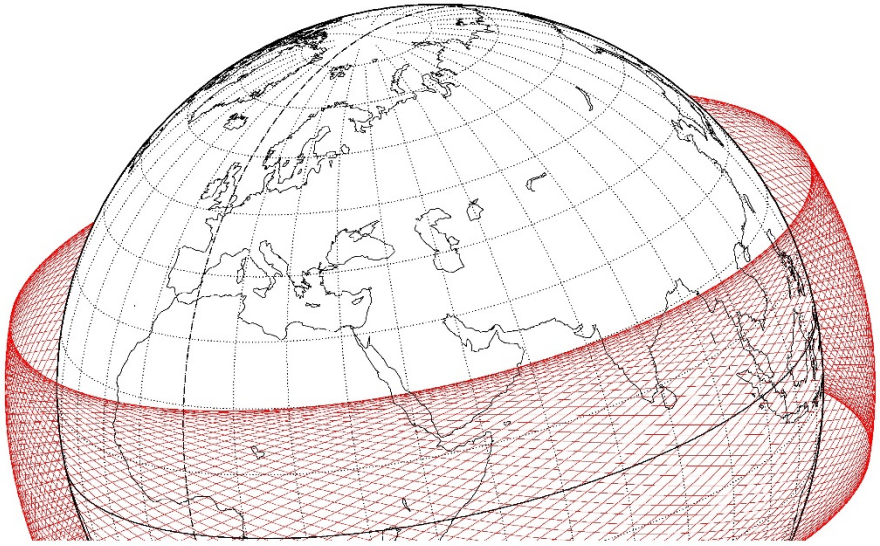

Aqua / CERES
15 ° N
YEAR
Altitude = 699.6 km * Inclination = 98.21 °* Half-swath = 61.8 ° ==> Max. Theta 78.0°-[J]= 8 * Th. 0 min.= 0.0°-[I]= 1
[I] Theta 0 - Solar Z. A.
[J] Theta - View. Z. A.
[K] Phi B - Relat. Az.
NDJ FMA MJJ ASO
MC ★ LMD
[I] =1
[I] =2
[I] =3
[I] =4
[I] =5
[I] =6
[I] =7
[I] =8
[I] =9
OSun/O = 50 %
Overpasses:1001 pts
Overpasses w.Sun: 503 pts
ASCENDING NODE (AN) : * Longitude AN = 166.38 °E * Date = 2014 09 09 * Time = 13h 36min LMT / AN
During 365 days. * [S] J=1 : Yr Mn Dy 2014 09 01 * [T] J=1 : Yr Mn Dy 2014 09 01
Point P
Latitude : 15.0 ° N
Longitude : 0.0 °


Terra / CERES
15 ° N
YEAR
Altitude = 699.6 km * Inclination = 98.21 °* Half-swath = 61.8 ° ==> Max. Theta 78.0°-[J]= 8 * Th. 0 min.= 0.0°-[I]= 1
[I] Theta 0 - Solar Z. A.
[J] Theta - View. Z. A.
[K] Phi B - Relat. Az.
NDJ FMA MJJ ASO
MC ★ LMD
[I] =1
[I] =2
[I] =3
[I] =4
[I] =5
[I] =6
[I] =7
[I] =8
[I] =9
OSun/O = 51 %
Overpasses:1001 pts
Overpasses w.Sun: 515 pts
ASCENDING NODE (AN) : * Longitude AN = 39.09 °W * Date = 2014 09 10 * Time = 22h 30min LMT / AN
During 365 days. * [S] J=1 : Yr Mn Dy 2014 09 01 * [T] J=1 : Yr Mn Dy 2014 09 01
Point P
Latitude : 15.0 ° N
Longitude : 0.0 °


Suomi-NPP / CERES
15 ° N
YEAR
Altitude = 824.1 km * Inclination = 98.78 °* Half-swath = 60.0 ° ==> Max. Theta 78.0°-[J]= 8 * Th. 0 min.= 0.0°-[I]= 1
[I] Theta 0 - Solar Z. A.
[J] Theta - View. Z. A.
[K] Phi B - Relat. Az.
NDJ FMA MJJ ASO
MC ★ LMD
[I] =1
[I] =2
[I] =3
[I] =4
[I] =5
[I] =6
[I] =7
[I] =8
[I] =9
OSun/O = 50 %
Overpasses:1119 pts
Overpasses w.Sun: 564 pts
ASCENDING NODE (AN) : * Longitude AN = 176.37 °E * Date = 2014 09 08 * Time = 13h 33min LMT / AN
During 365 days. * [S] J=1 : Yr Mn Dy 2014 09 01 * [T] J=1 : Yr Mn Dy 2014 09 01
Point P
Latitude : 15.0 ° N
Longitude : 0.0 °


Megha-Trop. / ScaRaB
15 ° N
YEAR
Altitude = 865.5 km * Inclination = 19.98 °* Half-swath = 48.9 ° ==> Max. Theta 58.9°-[J]= 6 * Th. 0 min.= 0.0°-[I]= 1
[I] Theta 0 - Solar Z. A.
[J] Theta - View. Z. A.
[K] Phi B - Relat. Az.
NDJ FMA MJJ ASO
MC ★ LMD
[I] =1
[I] =2
[I] =3
[I] =4
[I] =5
[I] =6
[I] =7
[I] =8
[I] =9
OSun/O = 52 %
Overpasses:2072 pts
Overpasses w.Sun:1068 pts
ASCENDING NODE (AN) : * Longitude AN = 121.32 °E * Date = 2014 06 01 * Time = 08h 30min LMT / AN
During 365 days. * [S] J=1 : Yr Mn Dy 2014 06 01 * [T] J=1 : Yr Mn Dy 2014 06 01
Point P
Latitude : 15.0 ° N
Longitude : 0.0 °

Sampling for the Tropical Zone



3

Megha-Tropiques

Orbit - ref.: Earth

Altitude = 865.5 km a = 7243.677 km

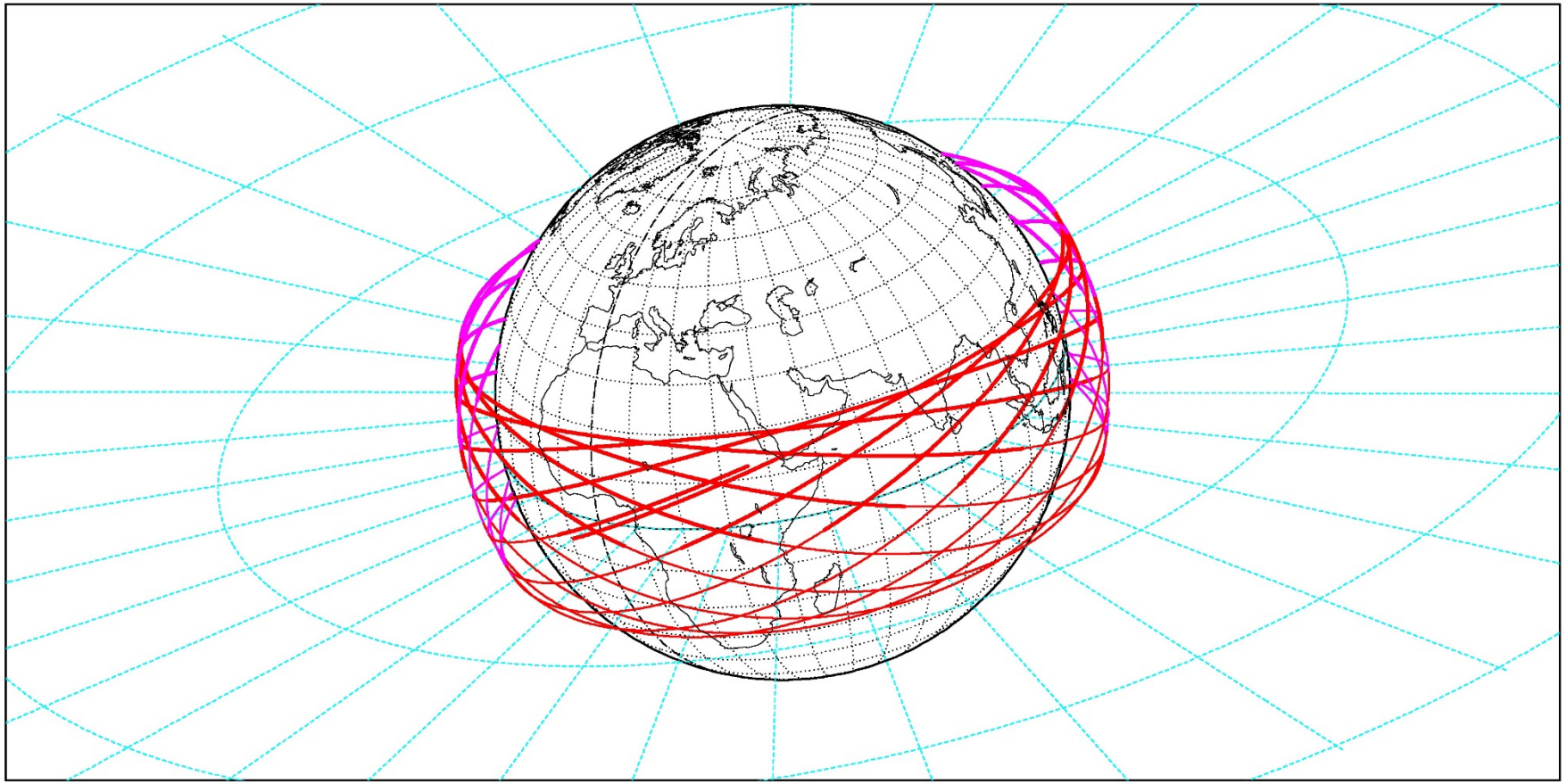
Inclination = 20.00 °

Recurrence = [14; -1; 7] 97

Period = 101.93 min * rev/day =14.13

>>>> Time span shown: 1440.0 min = 1.00 day

Equat. orbital shift = 2892.0 km (26.0 °)



Projection: Orthographic

Property: none

⊕ T.:Azimuthal - Graticule: 10°

Project. centre: 26.0 ° N; 46.0 °E

Aspect: Oblique

{4.2}[-90.0/ +64.0/ +44.0] [+12] EIGEN-C3

Asc. Node: 0.00 °

Ιξιων

MC ★ LMD

Ατλας

Megha-Tropiques / ScaRaB

Orbit - ref.: Earth

Altitude = 865.5 km a = 7243.677 km

Inclination = 20.00 °

Recurrence = [14; -1; 7] 97

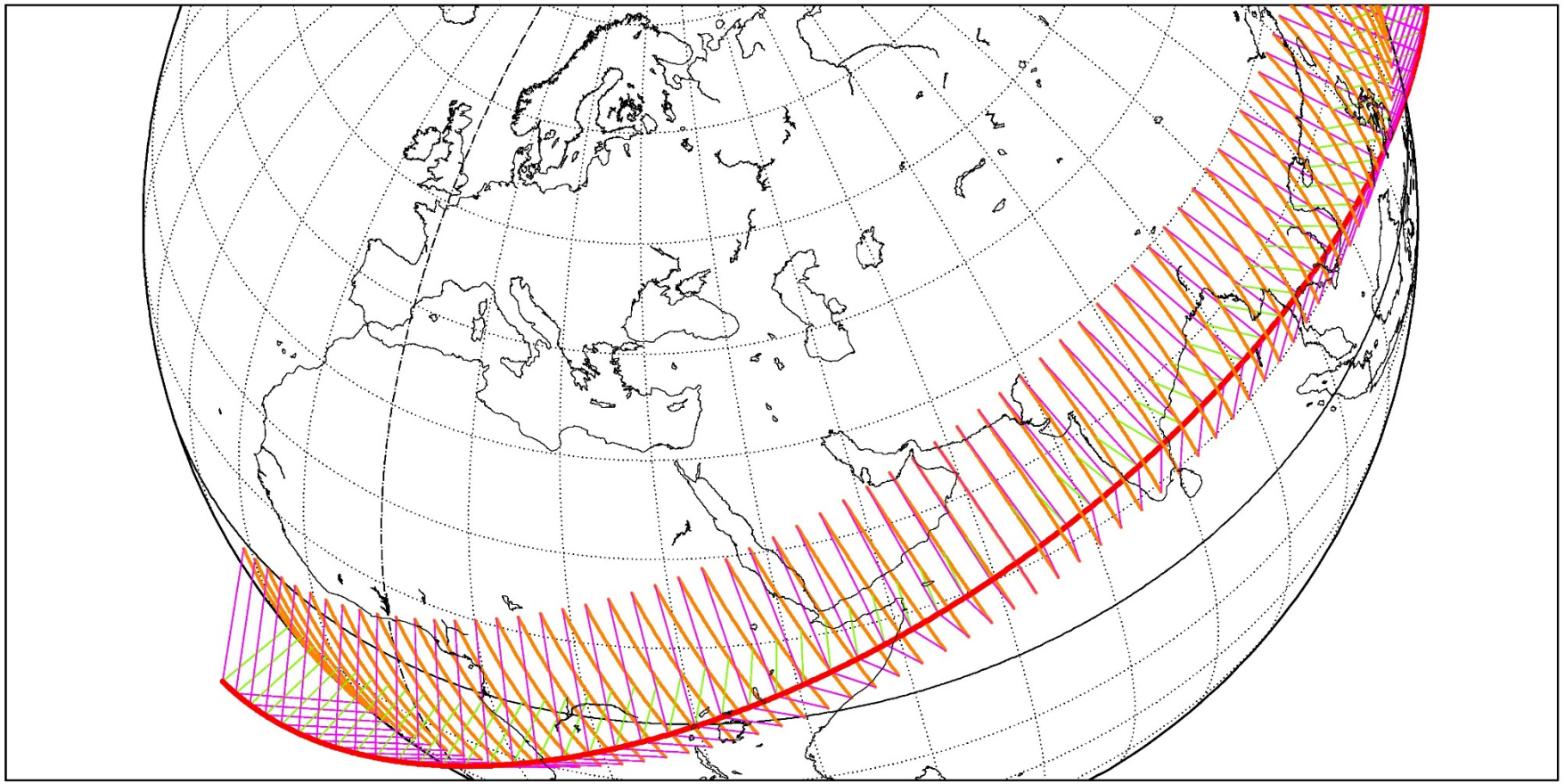
Period = 101.93 min * rev/day =14.13

>>>> Time span shown: 60.0 min = 0.04 day

Equat. orbital shift = 2892.0 km (26.0 °)

Across track swath (XT mode)

** Half-swath: 48.9° => 1108 km [0.75 min]



Projection: Orthographic

Property: none

⊕ T.:Azimuthal - Graticule: 10°

PC: 50.0 ° N; 50.0 °E /ZC: 35.0 ° N; 45.0 ° E

Aspect: Oblique

{5.3} [-90.0/ +40.0/ +40.0] [+16] EIGEN-C3

Asc. Node: 12.00 ° [12:00 LMT]

Max. attained latit. = 30.0 °

Ιξιων

MC ★ LMD

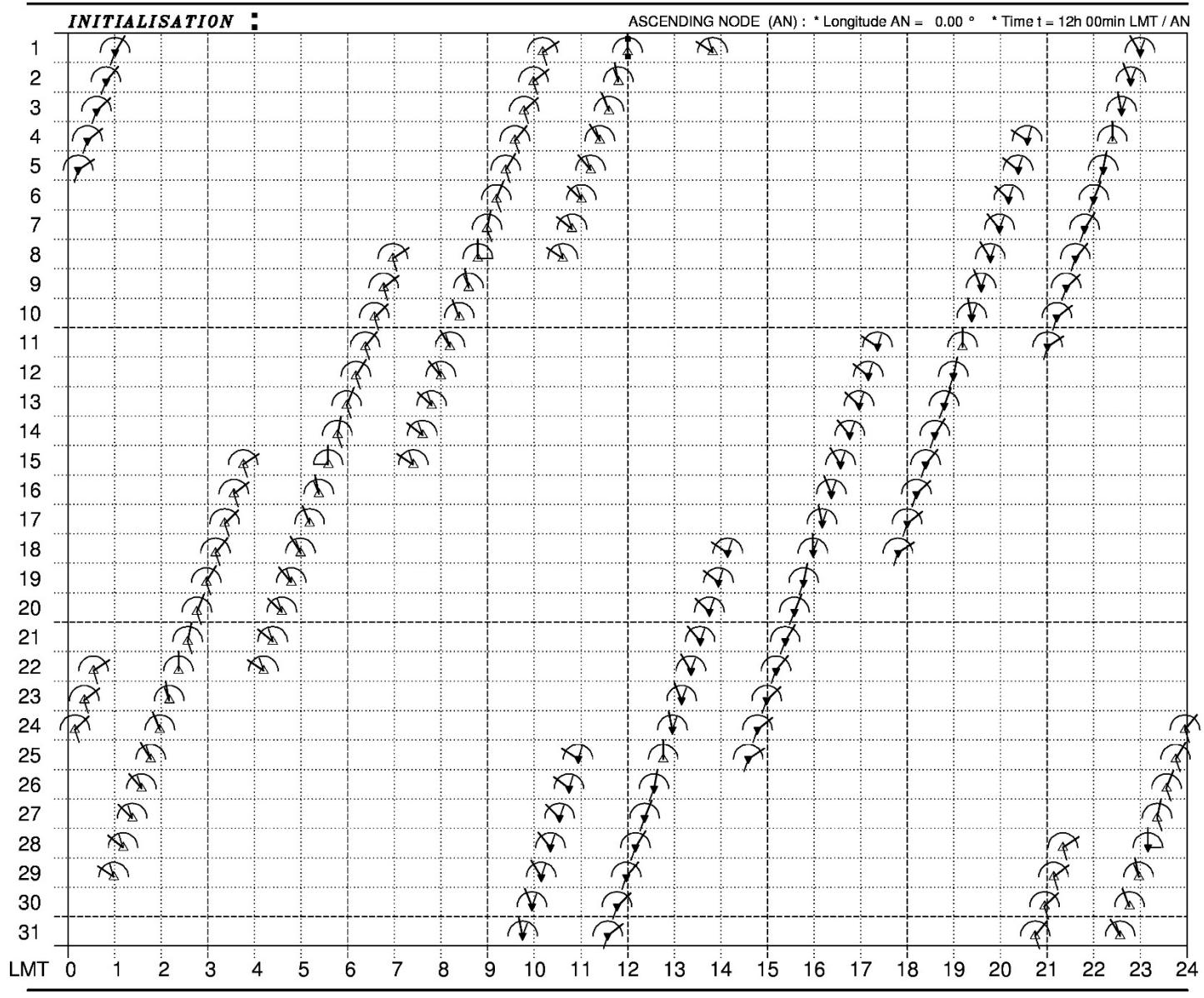
Ατλας

Recurrence cycle = 7 days [14; -1; 7] 97
Precess. cycle= 51 days (Cs= -51.3)
***

Megha-Tropiques

0 °

MONTHLY TABLE



OVERPASSES (n = 136)
OF SATELLITE S [EGM2008]
FOR POINT P
- Latitude : 0.0 °
- Longitude : 0.0 °
For P: UTC = LMT + 00h 00m

FIELD OF VIEW : 97.8 °

(1) (2) P-S DIRECTION
△ ASC ▼ DES

Right-handed system

- Zenith angle (in the plane orthogonal to the track). (1)
- Azimuth (in the local horizontal plane) with respect to the North. (2)

ORBIT a = 7243.677 km
Altitude = 865.5 km
Inclination = 20.00 °
Equatorial shift= 2892.0 km
Period = 101.93 min
Mean mot. = 14.13 rev/day

SCANNING
Half-swath = 48.9 °
Maximal zenith angle = 58.9 °
H.-swath (ground) = 1108.2 km
Equatorial overlap = 2.089
Max. attained latit. = 30.0 °

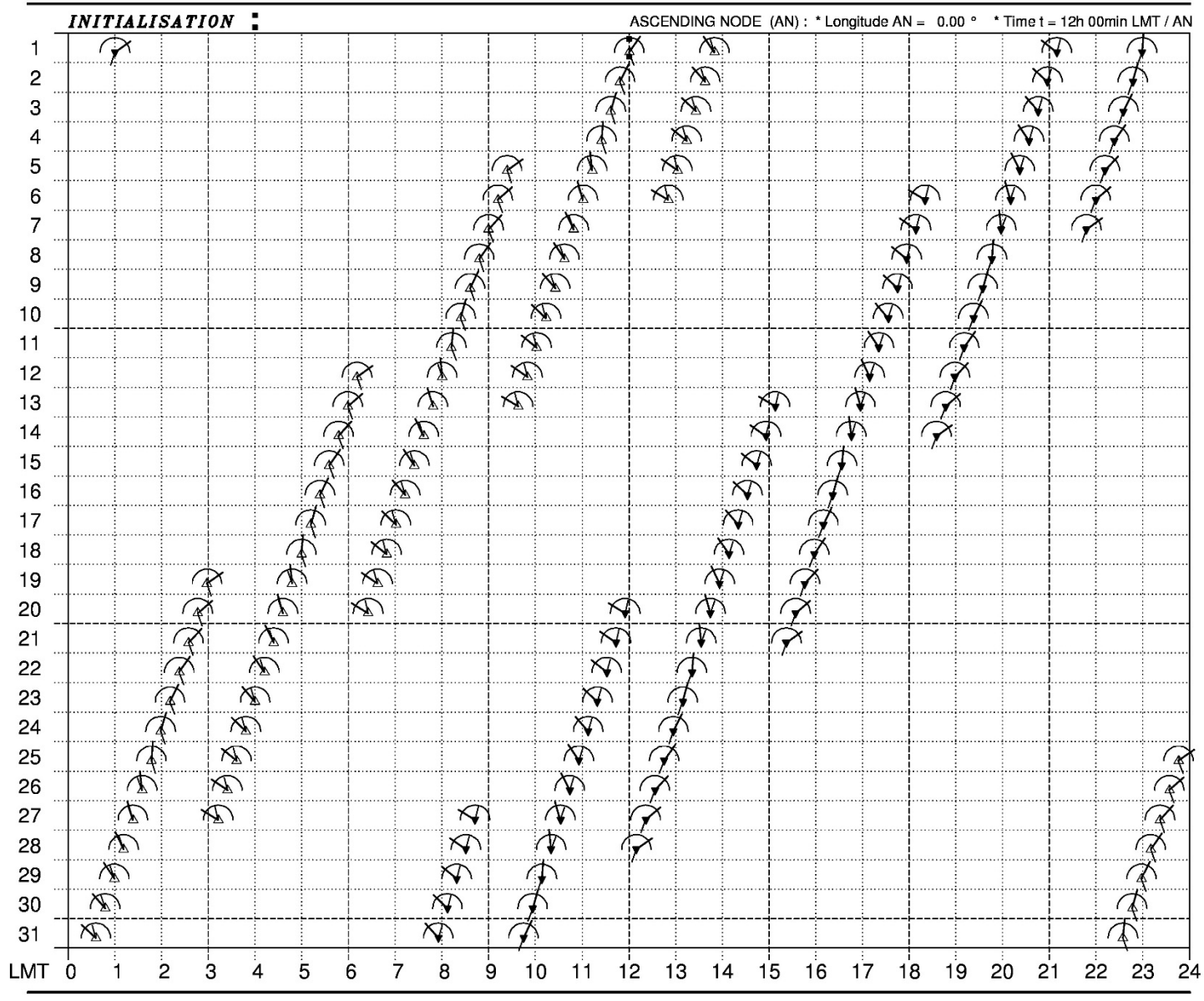
Ιξιων
MC ★ LMD

Recurrence cycle = 7 days [14; -1; 7] 97
Precess. cycle= 51 days (Cs= -51.3)
***

Megha-Tropiques

5 ° N

MONTHLY TABLE



OVERPASSES (n = 142)
OF SATELLITE S [EGM2008]
FOR POINT P
- Latitude : 5.0 ° N
- Longitude : 0.0 °
For P: UTC = LMT + 00h 00m

FIELD OF VIEW : 97.8 °

(1) (2) P-S DIRECTION
△ ASC ▼ DES

Right-handed system

- Zenith angle (in the plane orthogonal to the track). (1)
- Azimuth (in the local horizontal plane) with respect to the North. (2)

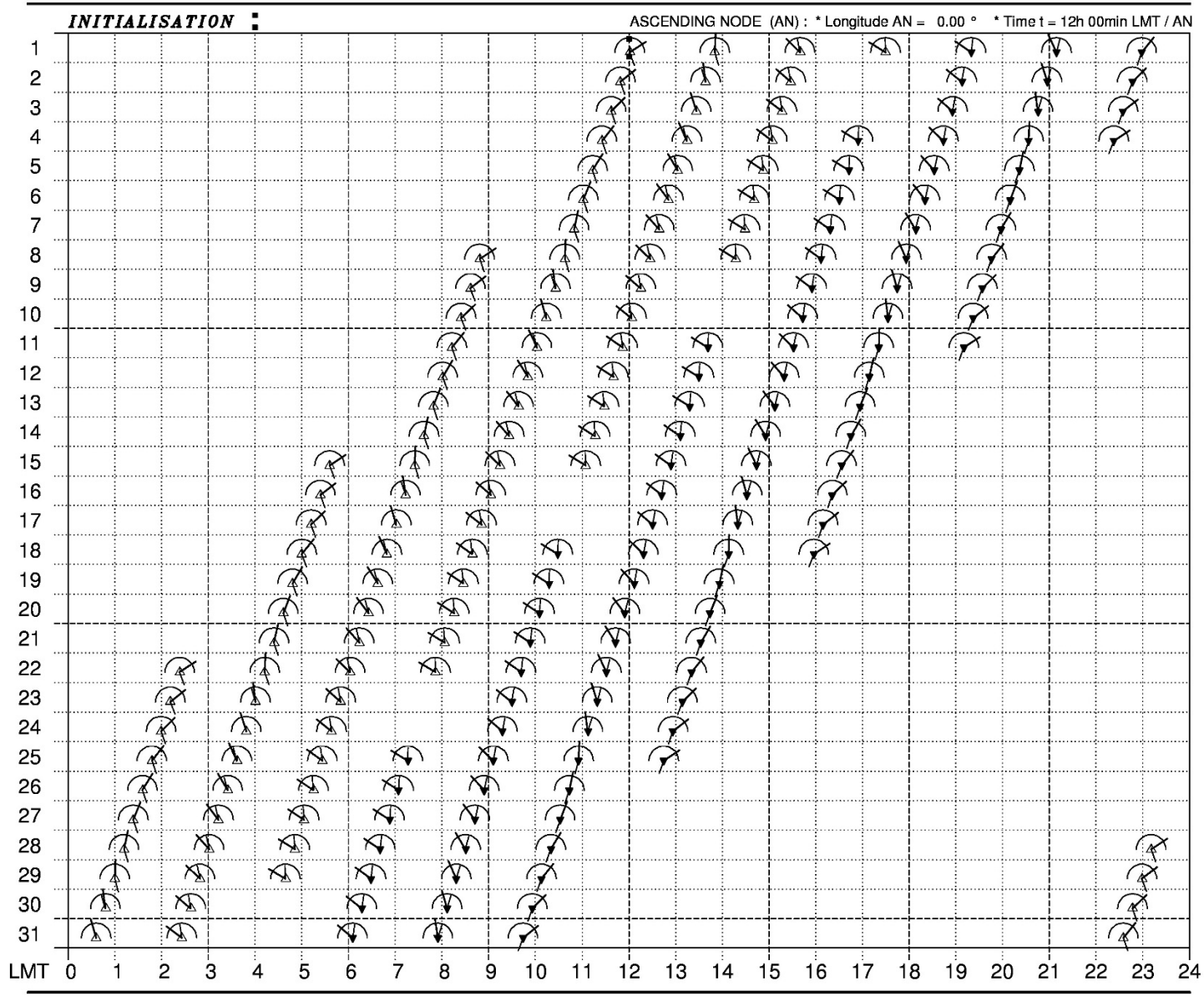
ORBIT a = 7243.677 km
Altitude = 865.5 km
Inclination = 20.00 °
Equatorial shift= 2892.0 km
Period = 101.93 min
Mean mot. = 14.13 rev/day

SCANNING
Half-swath = 48.9 °
Maximal zenith angle = 58.9 °
H.-swath (ground) = 1108.2 km
Equatorial overlap = 2.089
Max. attained latit. = 30.0 °

Ιξιων
MC ★ LMD

Recurrence cycle = 7 days [14; -1; 7] 97
Precess. cycle= 51 days (Cs= -51.3)
***

Megha-Tropiques



10 ° N MONTHLY TABLE

OVERPASSES (n = 196)
OF SATELLITE S [EGM2008]
FOR POINT P
- Latitude : 10.0 ° N
- Longitude : 0.0 °
For P: UTC = LMT + 00h 00m

FIELD OF VIEW : 97.8 °

(1) (2) P-S DIRECTION
△ ASC ▼ DES

Right-handed system

- Zenith angle (in the plane orthogonal to the track). (1)
- Azimuth (in the local horizontal plane) with respect to the North. (2)

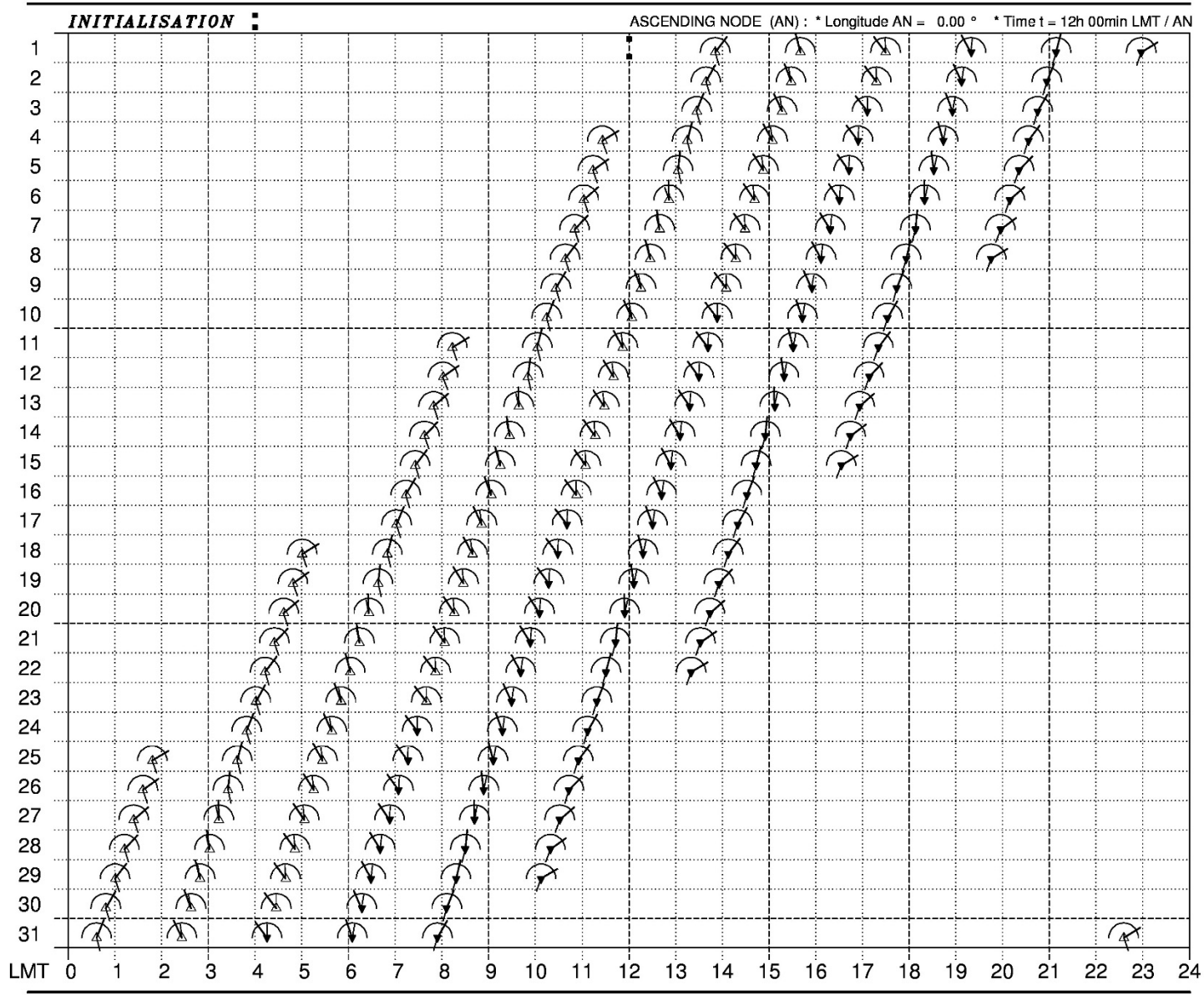
ORBIT a = 7243.677 km
Altitude = 865.5 km
Inclination = 20.00 °
Equatorial shift= 2892.0 km
Period = 101.93 min
Mean mot. = 14.13 rev/day

SCANNING
Half-swath = 48.9 °
Maximal zenith angle = 58.9 °
H.-swath (ground) = 1108.2 km
Equatorial overlap = 2.089
Max. attained latit. = 30.0 °

Ιξιων
MC ★ LMD

Recurrence cycle = 7 days [14; -1; 7] 97
Precess. cycle= 51 days (Cs= -51.3)
***

Megha-Tropiques



15 ° N

MONTHLY TABLE

OVERPASSES (n = 177)
OF SATELLITE S [EGM2008]
FOR POINT P
- Latitude : 15.0 ° N
- Longitude : 0.0 °
For P: UTC = LMT + 00h 00m

FIELD OF VIEW : 97.8 °

(1) (2) P-S DIRECTION
△ ASC ▼ DES

Right-handed system

- Zenith angle (in the plane orthogonal to the track). (1)
- Azimuth (in the local horizontal plane) with respect to the North. (2)

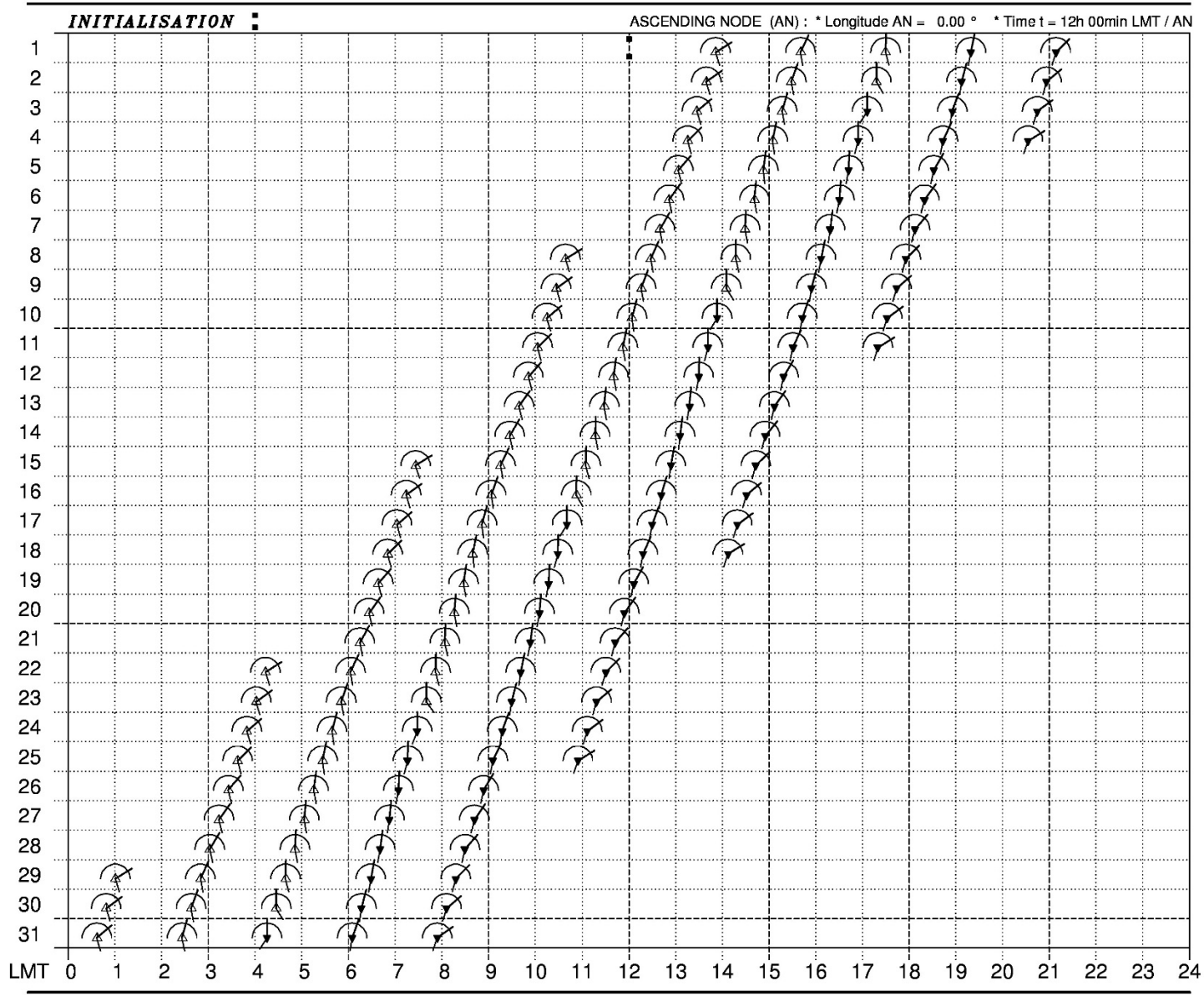
ORBIT a = 7243.677 km
Altitude = 865.5 km
Inclination = 20.00 °
Equatorial shift= 2892.0 km
Period = 101.93 min
Mean mot. = 14.13 rev/day

SCANNING
Half-swath = 48.9 °
Maximal zenith angle = 58.9 °
H.-swath (ground) = 1108.2 km
Equatorial overlap = 2.089
Max. attained latit. = 30.0 °

Ιξιων
MC ★ LMD

Recurrence cycle = 7 days [14; -1; 7] 97
Precess. cycle= 51 days (Cs= -51.3)
***

Megha-Tropiques



20 ° N

MONTHLY TABLE

OVERPASSES (n = 143)
OF SATELLITE S [EGM2008]
FOR POINT P
- Latitude : 20.0 ° N
- Longitude : 0.0 °
For P: UTC = LMT + 00h 00m

FIELD OF VIEW : 97.8 °

(1) (2) P-S DIRECTION
△ ASC ▼ DES

Right-handed system

- Zenith angle (in the plane orthogonal to the track). (1)
- Azimuth (in the local horizontal plane) with respect to the North. (2)

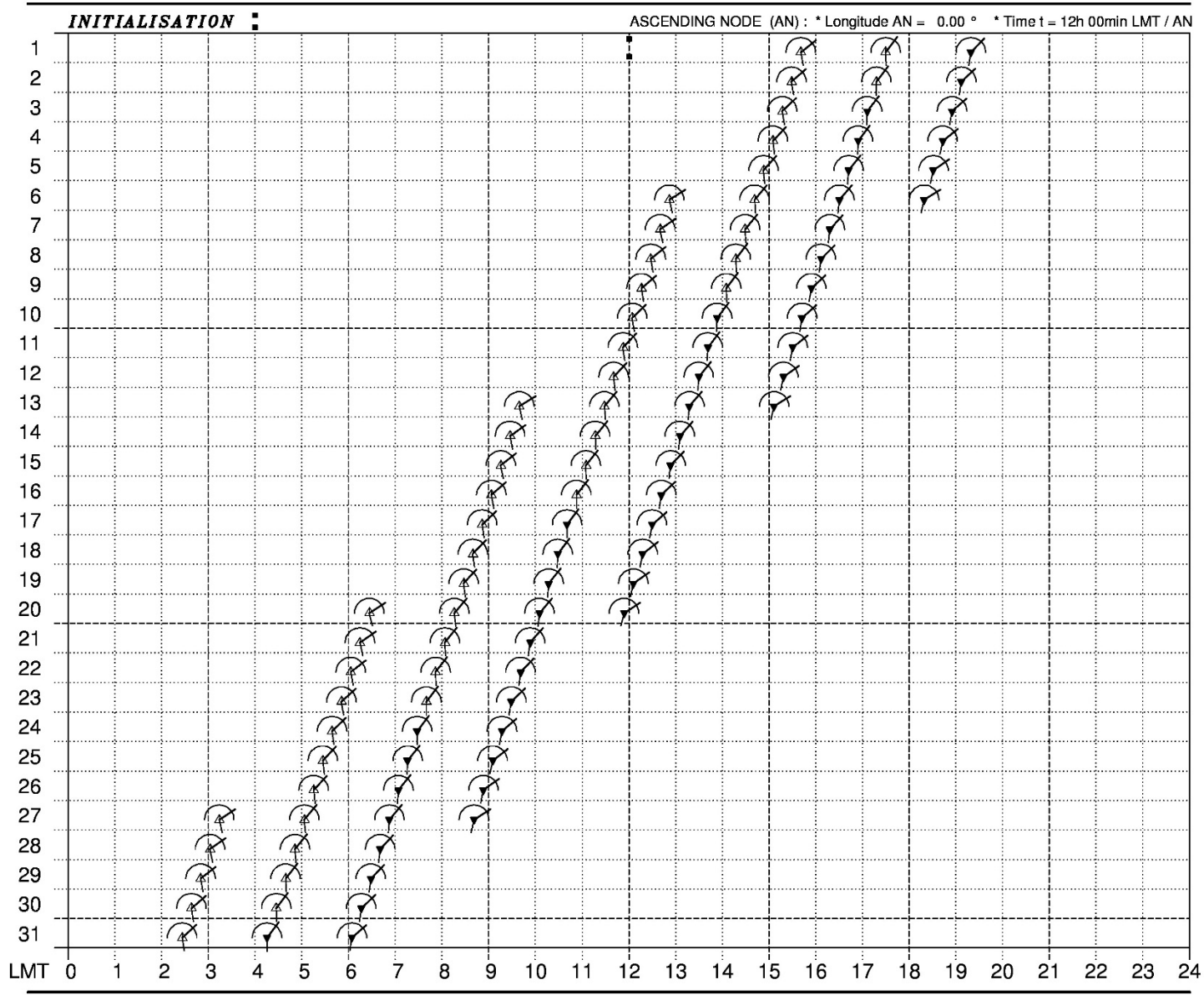
ORBIT a = 7243.677 km
Altitude = 865.5 km
Inclination = 20.00 °
Equatorial shift= 2892.0 km
Period = 101.93 min
Mean mot. = 14.13 rev/day

SCANNING
Half-swath = 48.9 °
Maximal zenith angle = 58.9 °
H.-swath (ground) = 1108.2 km
Equatorial overlap = 2.089
Max. attained latit. = 30.0 °

Ιξιων
MC ★ LMD

Recurrence cycle = 7 days [14; -1; 7] 97
Precess. cycle= 51 days (Cs= -51.3)
***

Megha-Tropiques



25 ° N

MONTHLY TABLE

OVERPASSES (n = 97)
OF SATELLITE S [EGM2008]
FOR POINT P
- Latitude : 25.0 ° N
- Longitude : 0.0 °
For P: UTC = LMT + 00h 00m

FIELD OF VIEW : 97.8 °

(1) (2) P-S DIRECTION
△ ASC ▼ DES

Right-handed system

- Zenith angle (in the plane orthogonal to the track). (1)
- Azimuth (in the local horizontal plane) with respect to the North. (2)

ORBIT a = 7243.677 km
Altitude = 865.5 km
Inclination = 20.00 °
Equatorial shift= 2892.0 km
Period = 101.93 min
Mean mot. = 14.13 rev/day

SCANNING
Half-swath = 48.9 °
Maximal zenith angle = 58.9 °
H.-swath (ground) = 1108.2 km
Equatorial overlap = 2.089
Max. attained latit. = 30.0 °

Ξιων
MC ★ LMD

- Particular point,

resulting of the 20-degree inclination:

for the latitudes between 10° and 25°

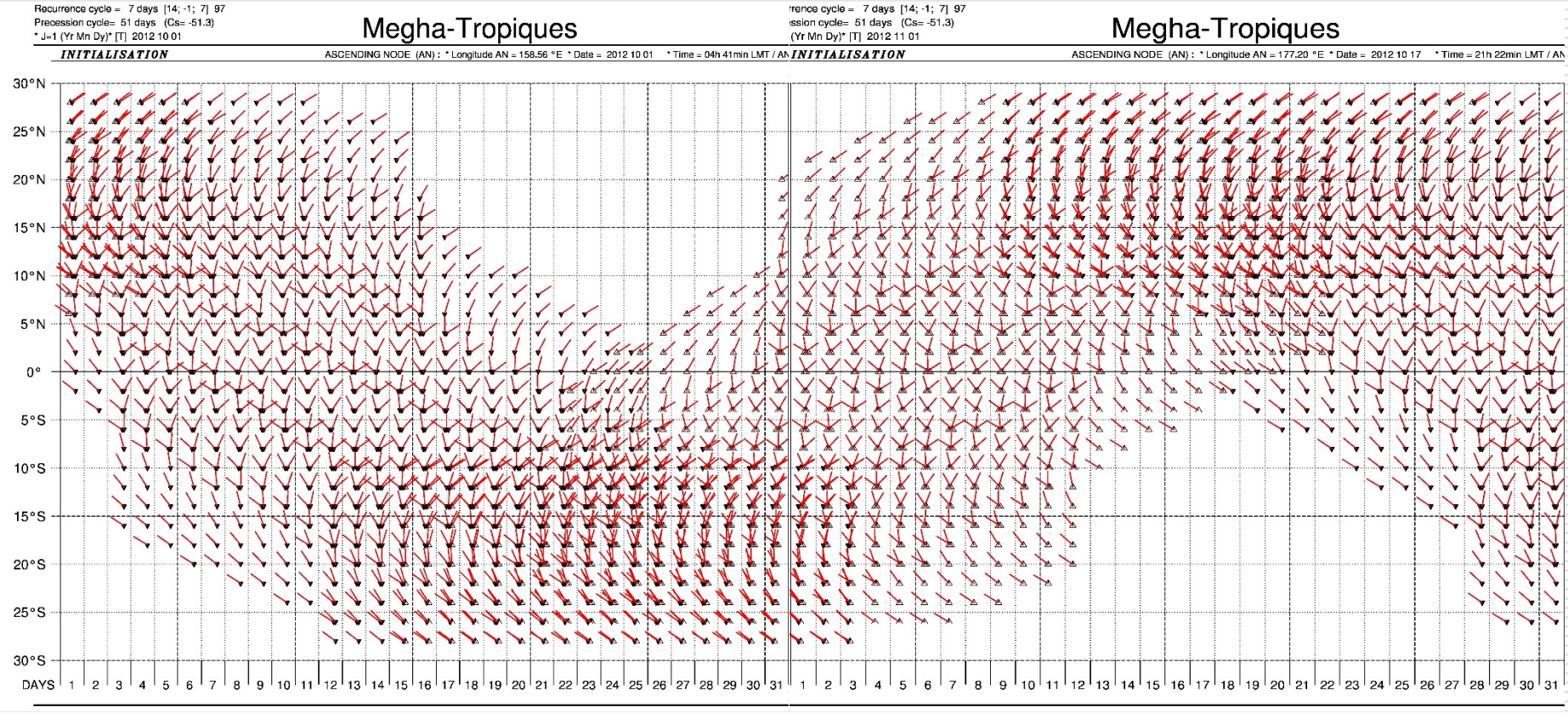
(North and South),

the ***temporal sampling*** is represented by

- a « pack » of overpasses
- followed by a « lack » (without overpass).

Sampling for the interval **07:00 – 17:00** (10 h. day-light between 7 am and 5 pm)

MT: **October** and **November** 2012



Megha-Tropiques / MADRAS
Orbit - Ground track

Altitude = 865.5 km a = 7243.678 km

Inclination = 20.00 °

Recurrence = [14; -1; 7] 97

Period = 101.93 min * rev/day =14.13

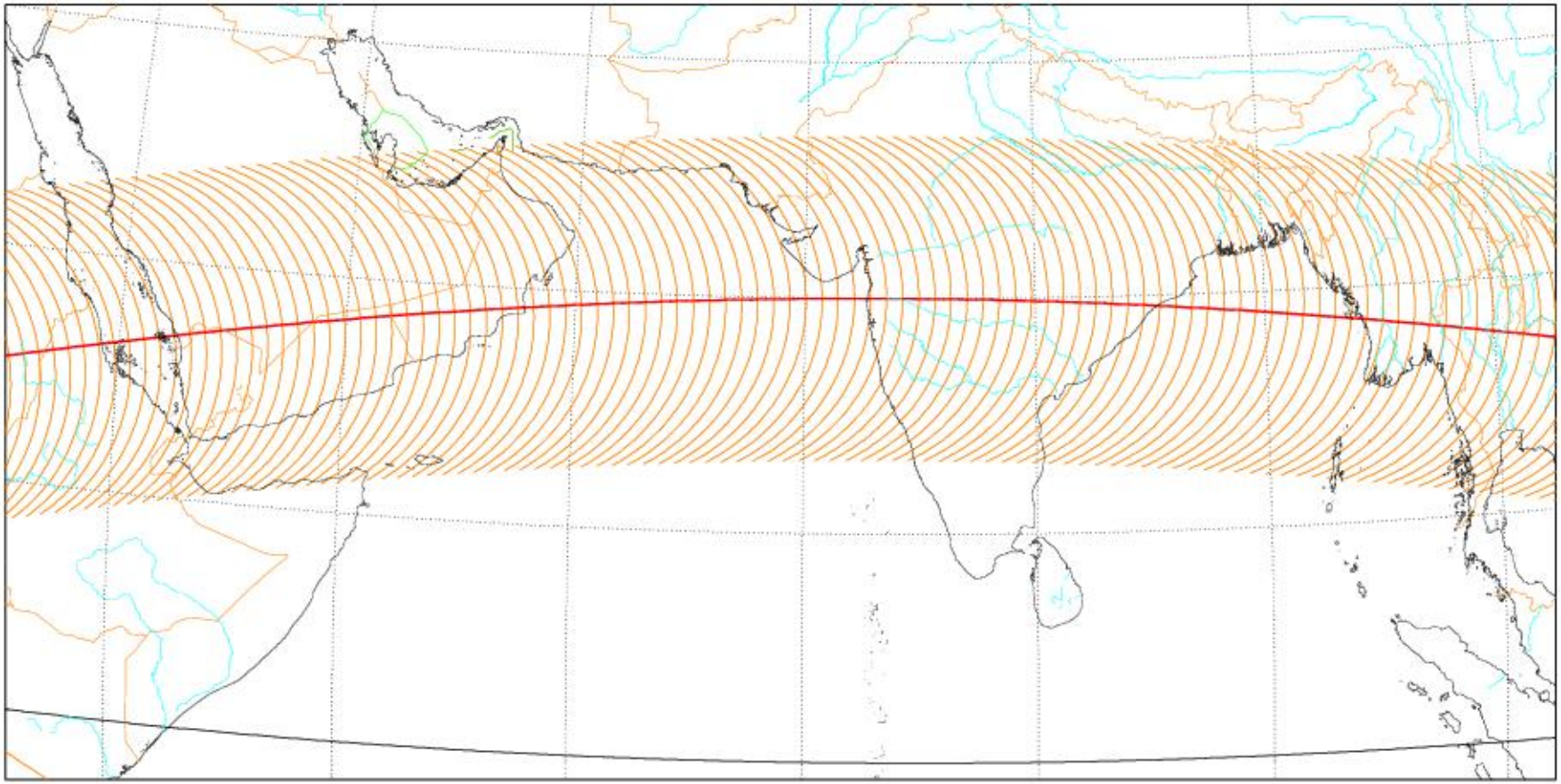
>>>> Time span shown: 100.0 min = 0.07 day

Equat. orbital shift = 2892.0 km (26.0 °)

Ground track - Conical swath / VZA=53.1 °

** Half-aperture: 65.0° - Radius/grnd 928 km [0.25 min]

** Effect. h-ap.: 42.3 ° => 841 km - Effect. swath: 1682 km



Projection: Raisz Armadillo

Property: none

⊕ T.:(various) - Graticule: 10°

MC: 0.0 ° ; 75.0 °E/ZC: 16.0 ° N; 69.0 ° E

Aspect: Direct **> zoom : 4.00**

{6.4}[+90.0/ +0.0/-165.0] [-] GEM-T2

Asc. node: -10.00 ° [00:00 LMT]

App. inclin. = 21.52 °

Max. attained latit. = 27.6 °

Ξιων

MC ★ LMD

Ατλας

Megha-Tropiques / ScaRaB
Orbit - Ground track

Altitude = 865.5 km a = 7243.678 km

Inclination = 20.00 °

Recurrence = [14; -1; 7] 97

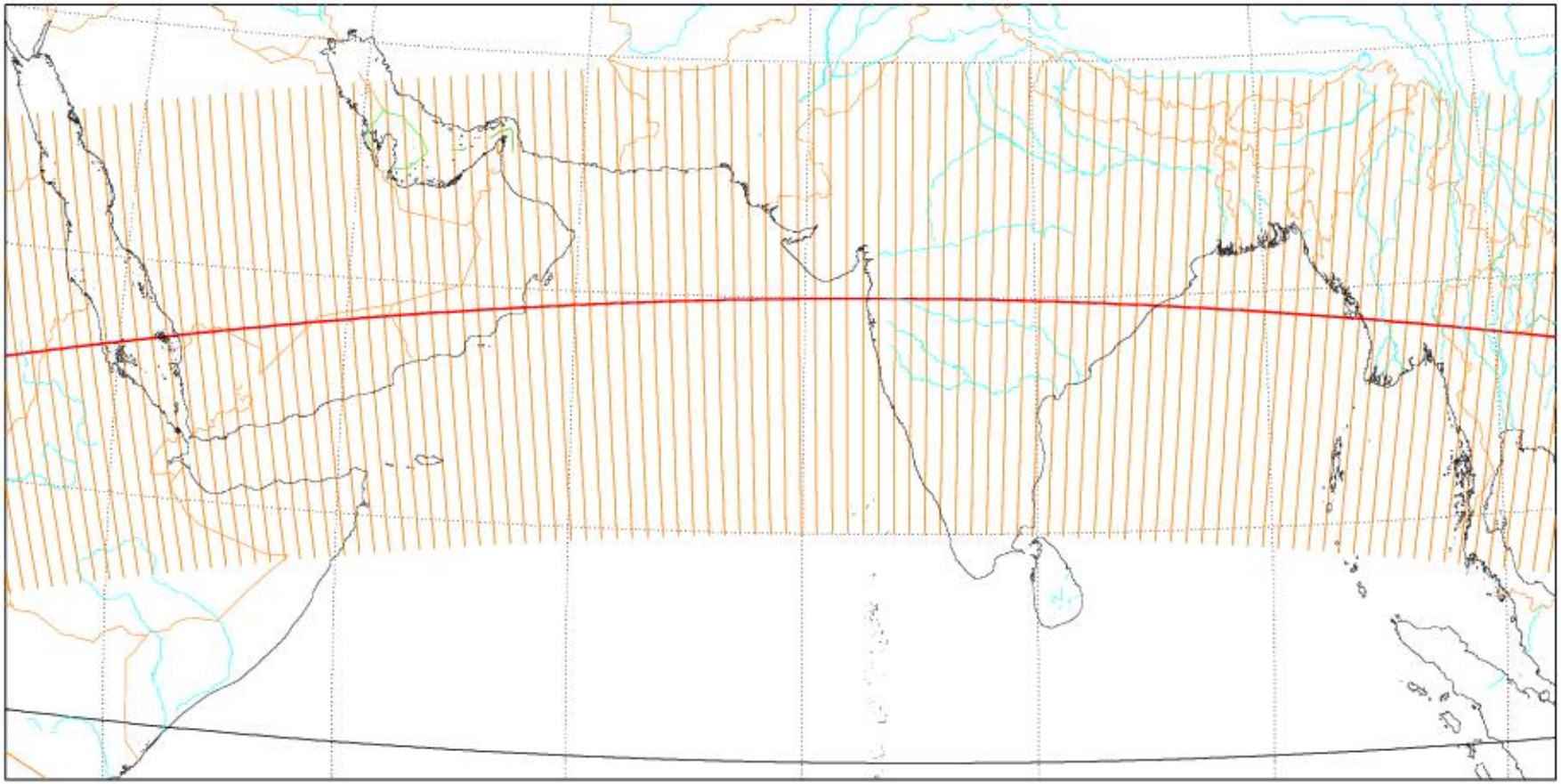
Period = 101.93 min * rev/day =14.13

>>>> Time span shown: 100.0 min = 0.07 day

Equat. orbital shift = 2892.0 km (26.0 °)

Across track swath (XT mode)

** Half-swath: 48.9° => 1108 km [0.25 min]



Projection: Raisz Armadillo

Property: none

⊕ T.:(various) - Graticule: 10°

MC: 0.0 ° ; 75.0 °E/ZC: 16.0 ° N; 69.0 ° E

Aspect: Direct **> zoom : 4.00**

{6.4}[+90.0/ +0.0/-165.0] [-] GEM-T2

Asc. node: -10.00 ° [00:00 LMT]

App. inclin. = 21.52 °

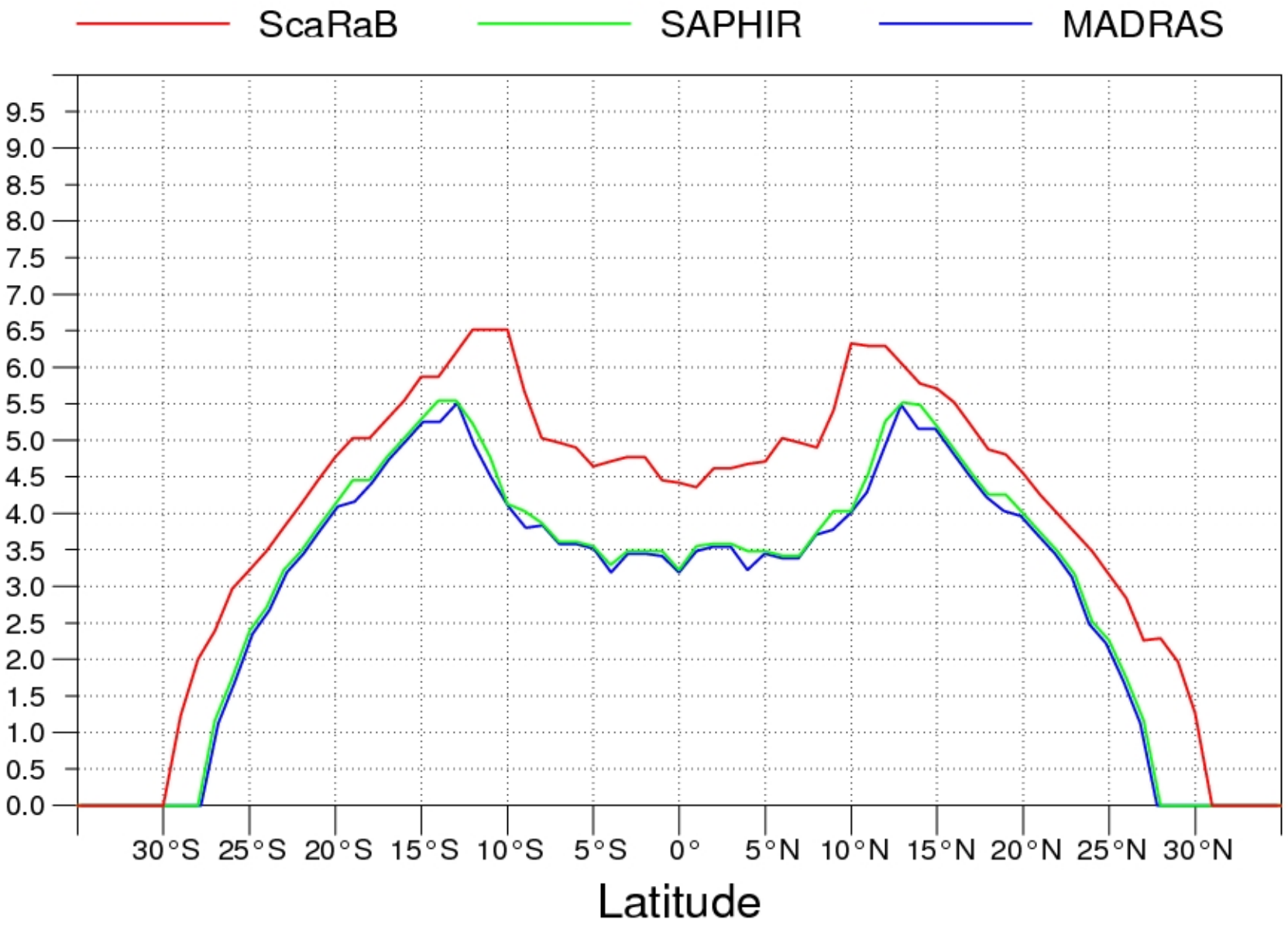
Max. attained latit. = 30.0 °

Ιξιων

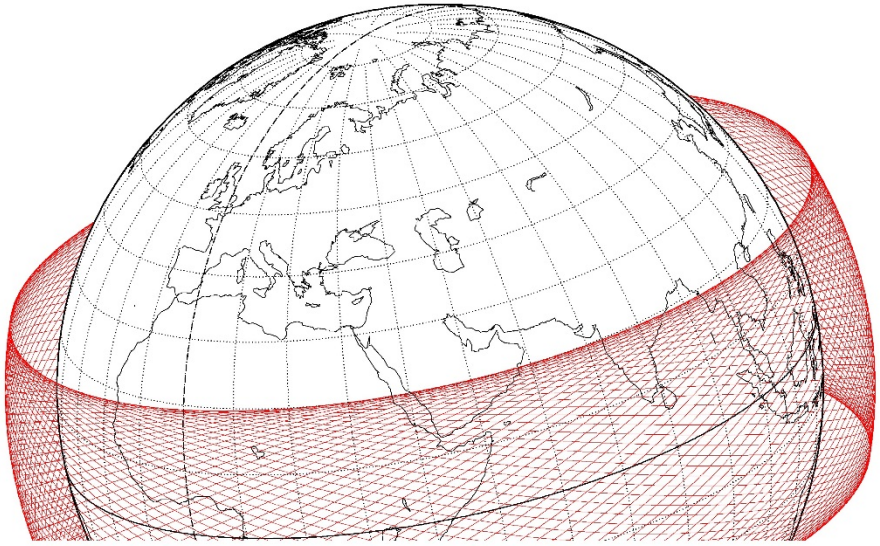
MC ★ LMD

Ατλας

Mean number of overpasses



Megha-Tropiques and Terra Rendez-vous

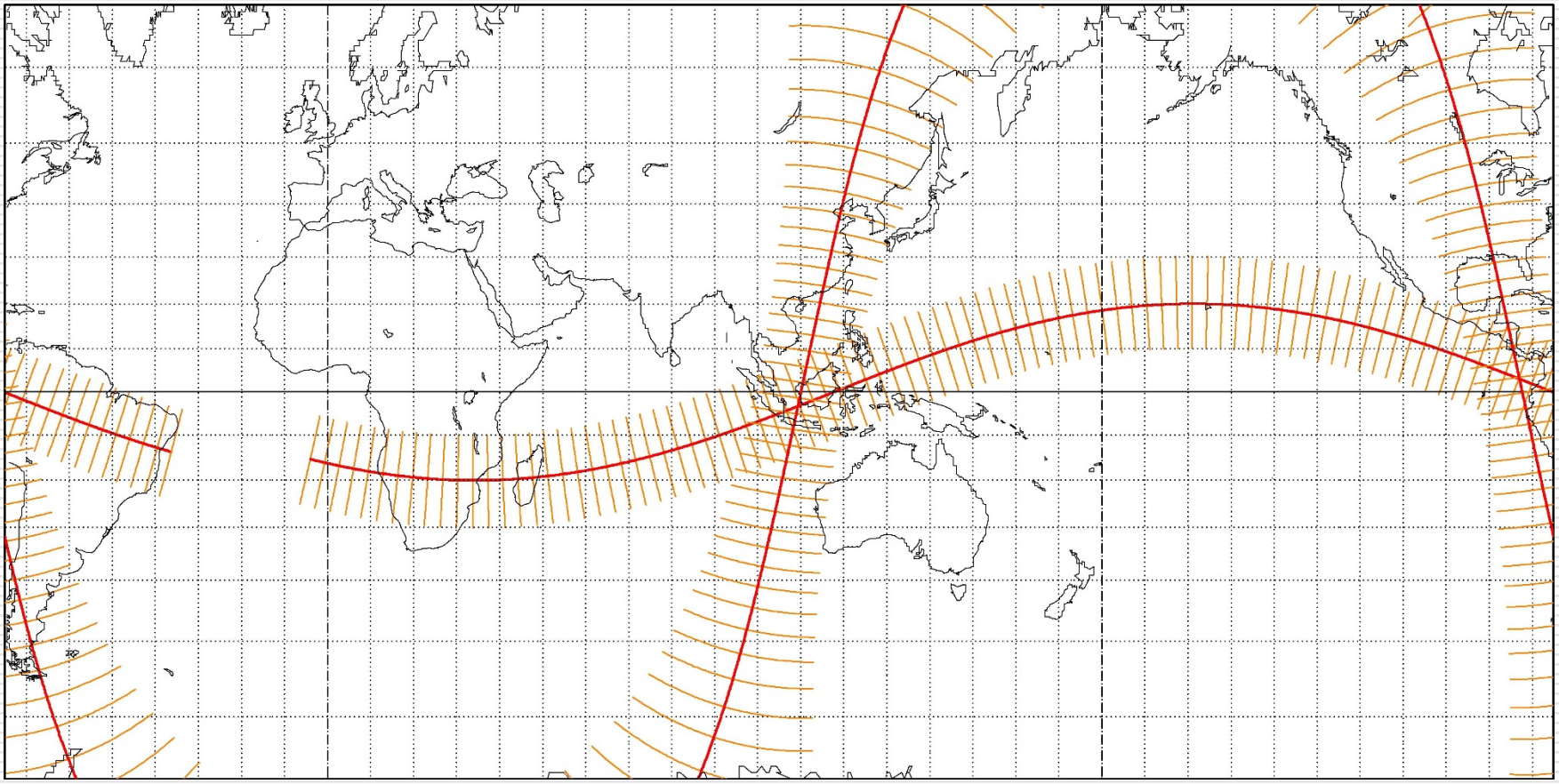


4

Megha-Tropiques / ScaRaB and Terra / CERES

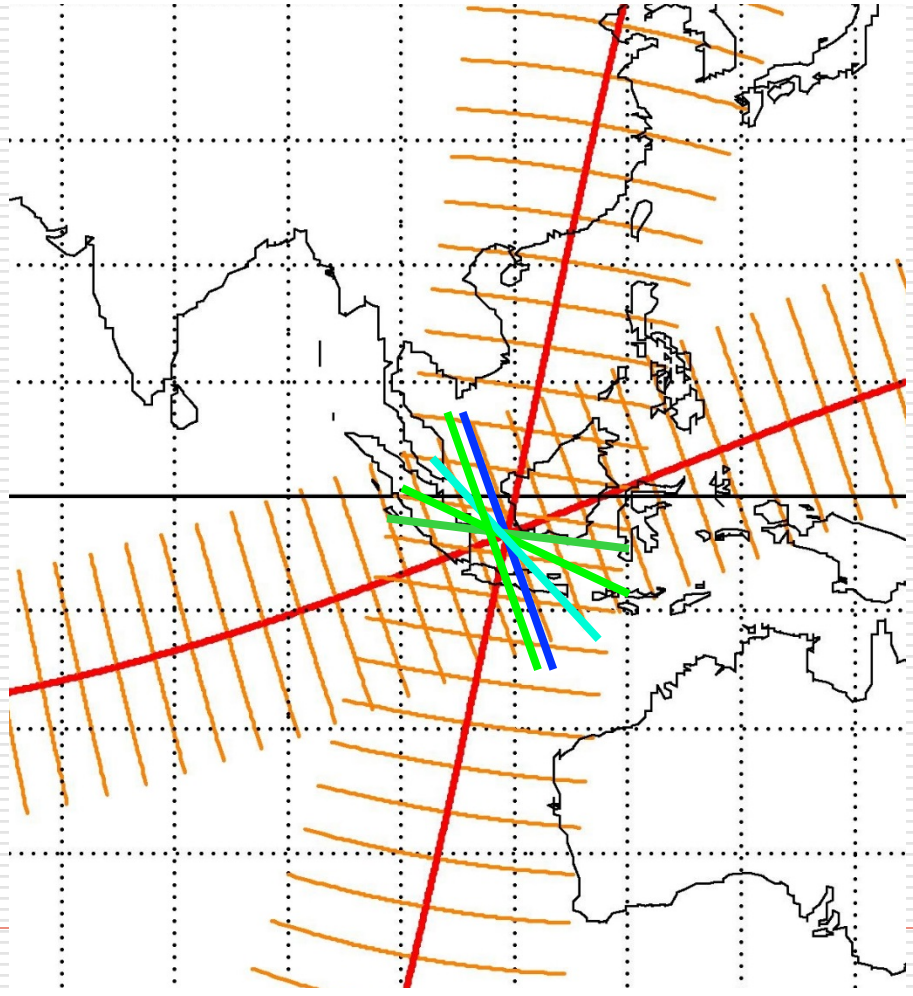
In-space and in-time **Rendez-vous**

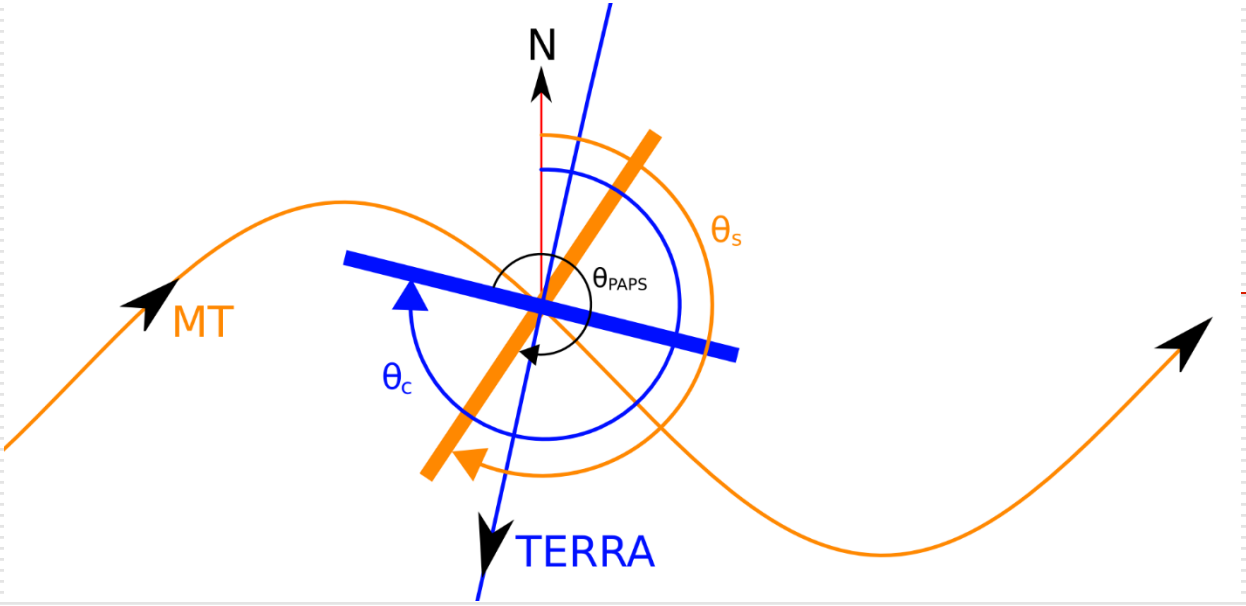
- Example: April 17, 2012. 03:10 UTC



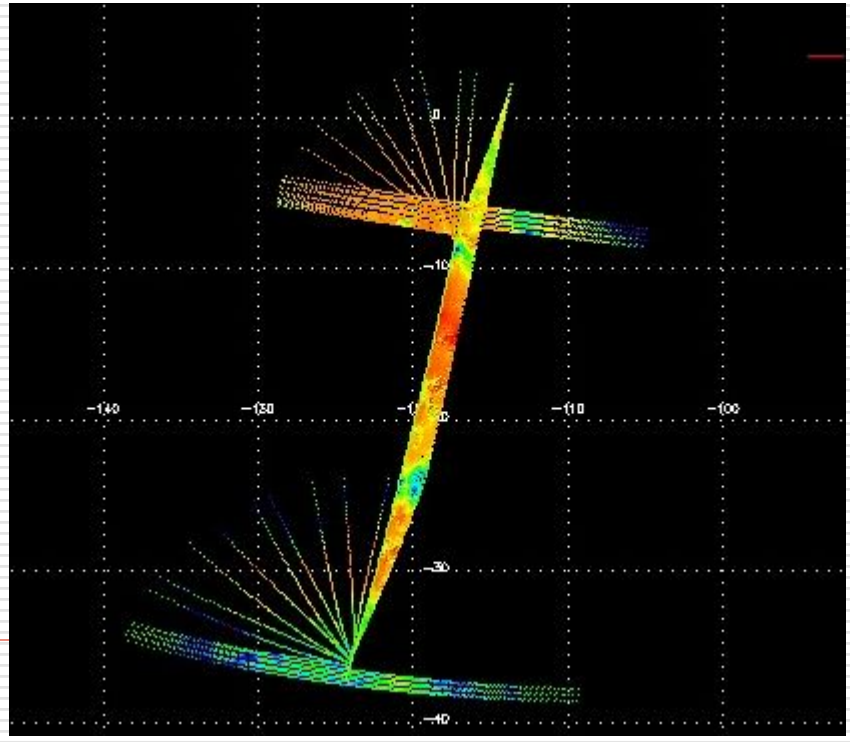
Megha-Tropiques / ScaRaB and Terra / CERES

In-space and in-time **Rendez-vous**





- Swath Geometry for ScaRaB / MT and CERES/Terra



Megha-Tropiques

0 km <-> 1760 km - Locations of overlapping with Terra
[+/- 4.0 min]

Recurrence = [14; -1; 7] 97

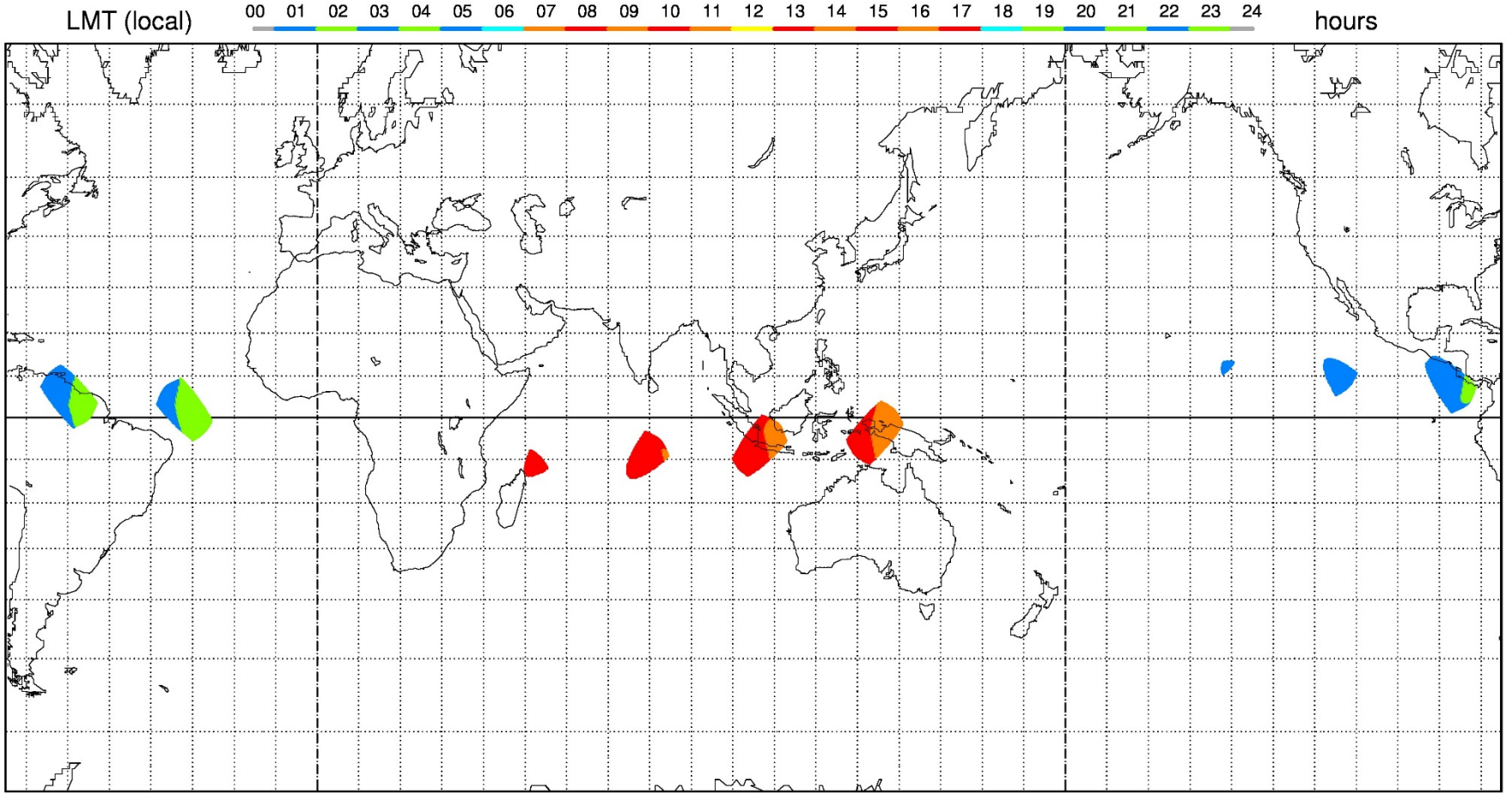
2012 04 17 00:00:00 UTC >>> 1440.0 min = 1.00 day

Altitude = 865.5 km a = 7243.599 km

Inclination = 19.98 ° e = 0.001019

Period = 101.93 min * rev/day =14.13

*** [+/- 1108 km] Megha-Trop *** [+/- 1165 km] Terra

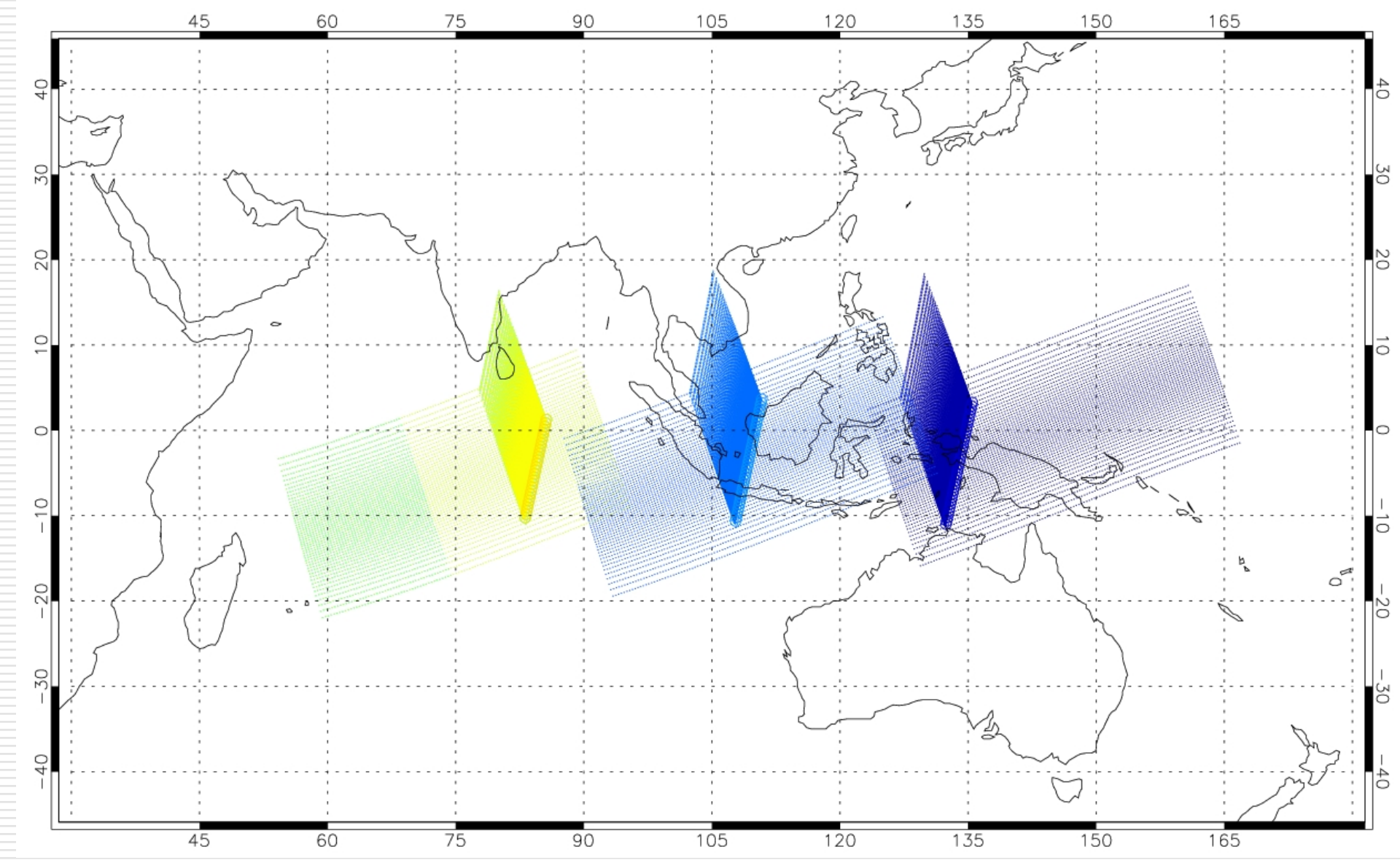


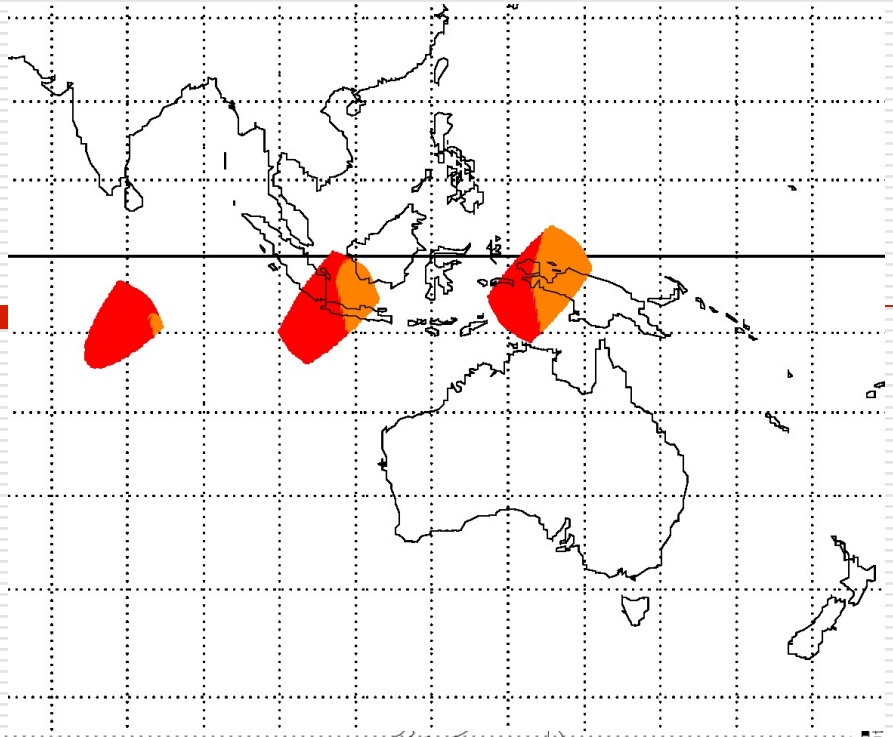
Projection: Mercator
Property: Conformal
⊕ T.:Cylindrical - Graticule: 10°

Project. centre: 0.0 ° ; 105.0 °E
Aspect: Direct
{4.2}[+90.0/ +0.0/+165.0] [-] EIGEN-C3

Asc. Node: 162.23 ° [13:29 LMT]
[NORAD] Revolution: 2581
[NORAD] 2012 04 12 02:39:35 UTC

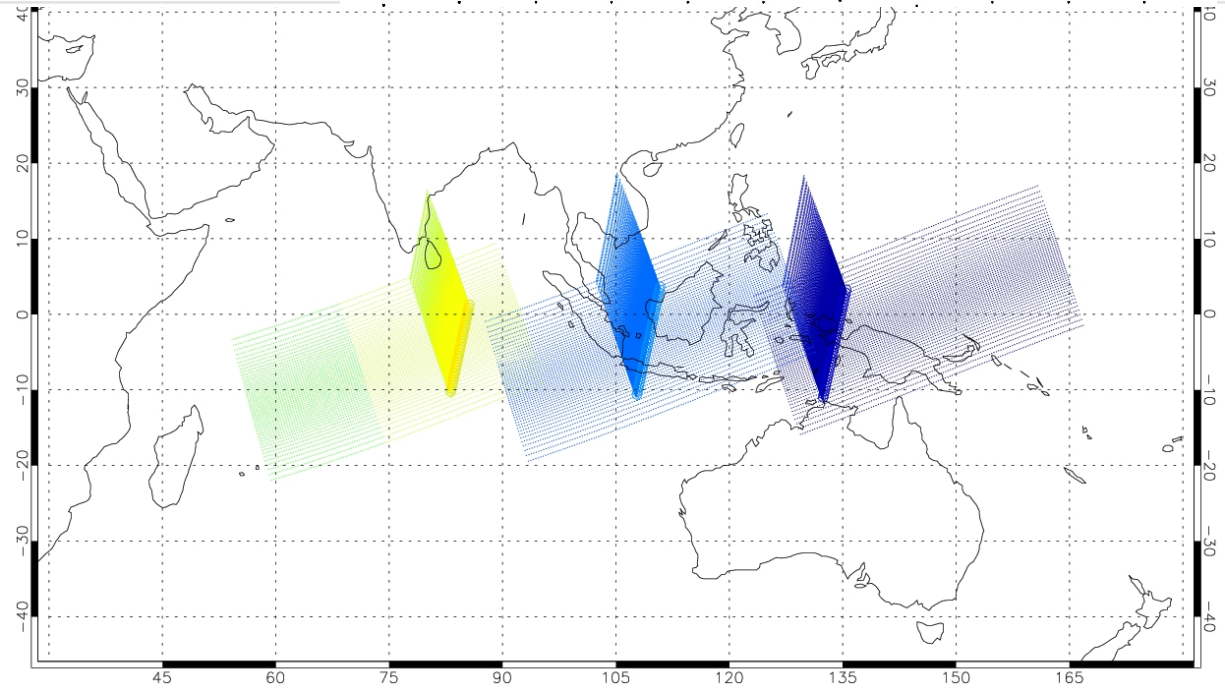
Ιξιων
MC ★ LMD
Ατλας


45
60
75
90
105
120
135
150
165
40
30
20
10
0
−10
−20
−30
−40



Prediction
by Ixion.

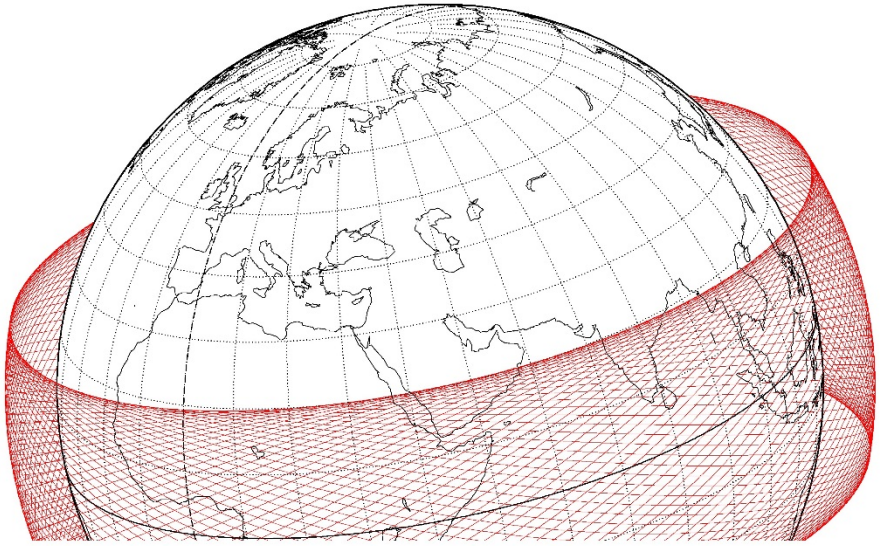
Norad (Two-Line Elements)
5 days in advance.



Results

with pixel coordinate provided by
the space agencies:
NASA for Terra,
ISRO for Megha-Tropiques.

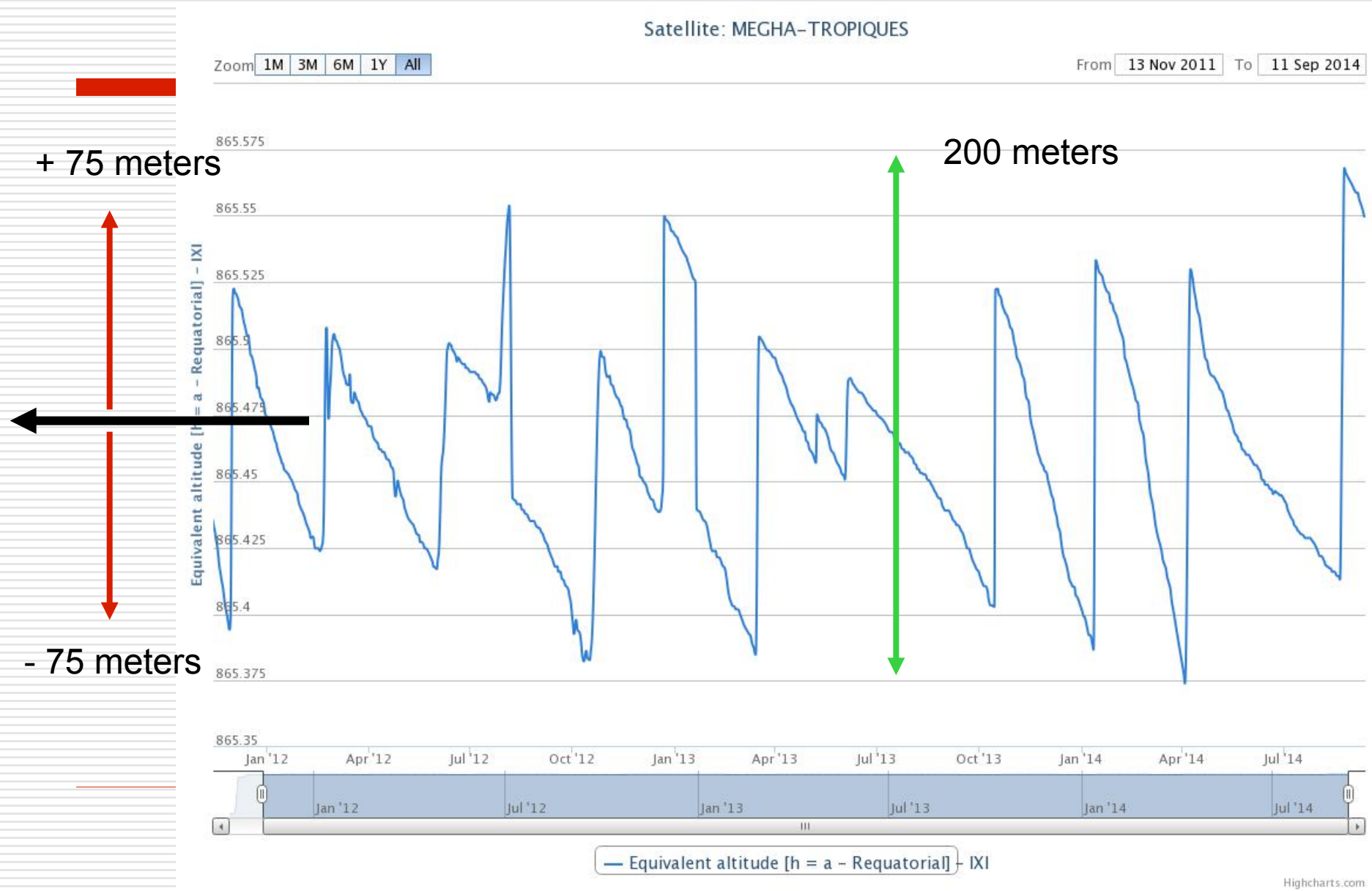
Orbit Mantenance



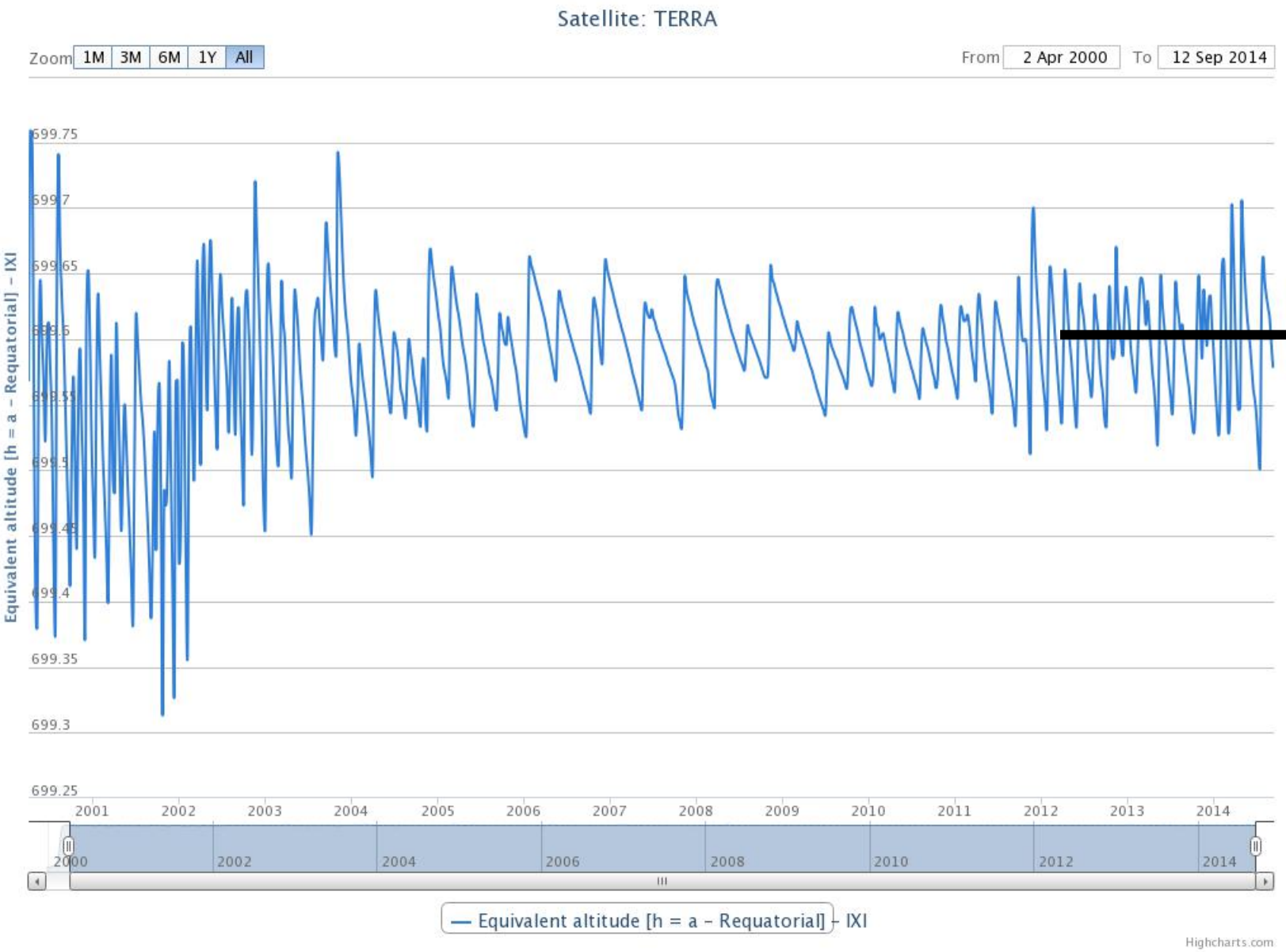
5

MT: a very accurate Orbit Maintenance

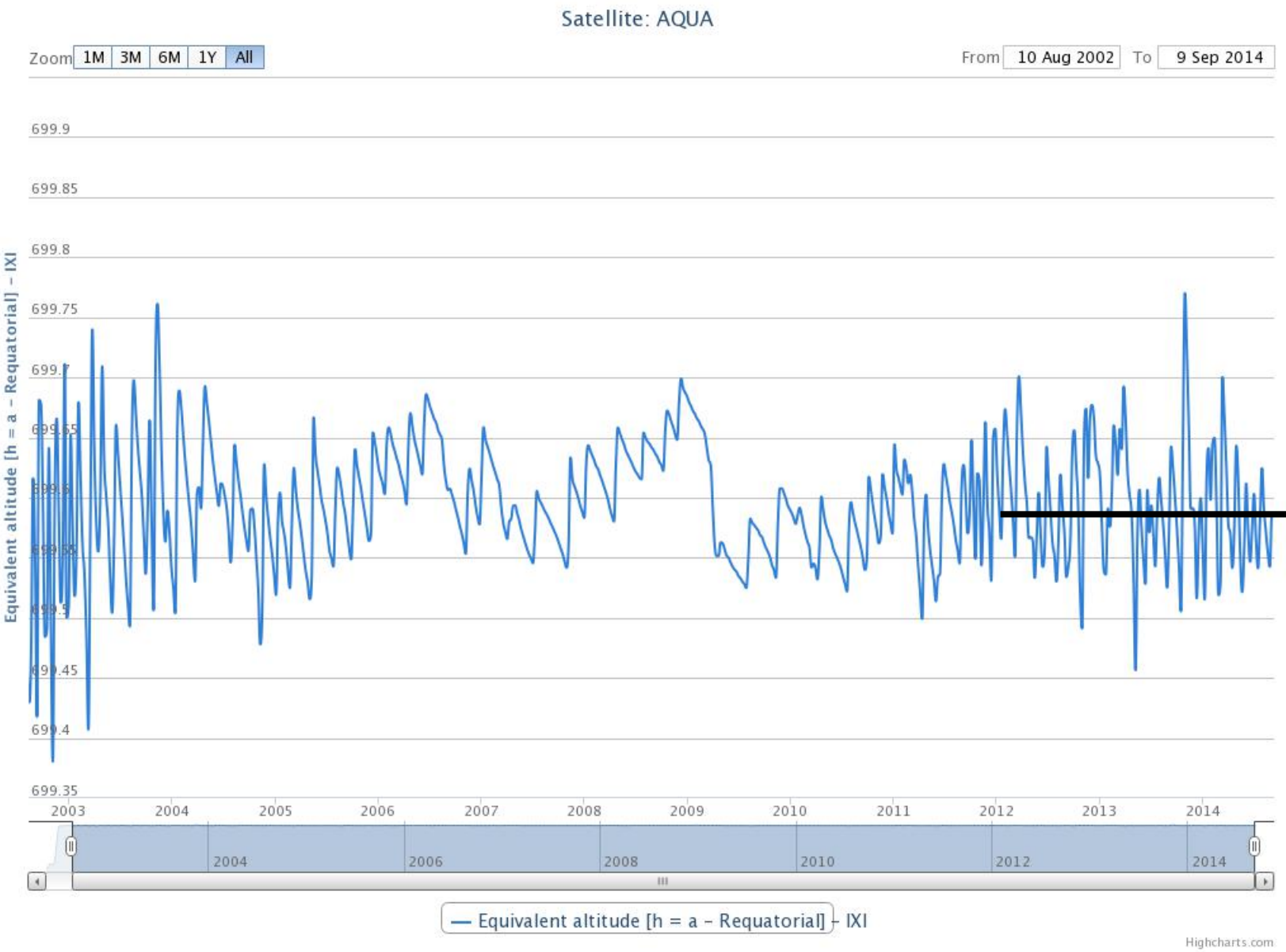
Equivalent altitude: h = a - R



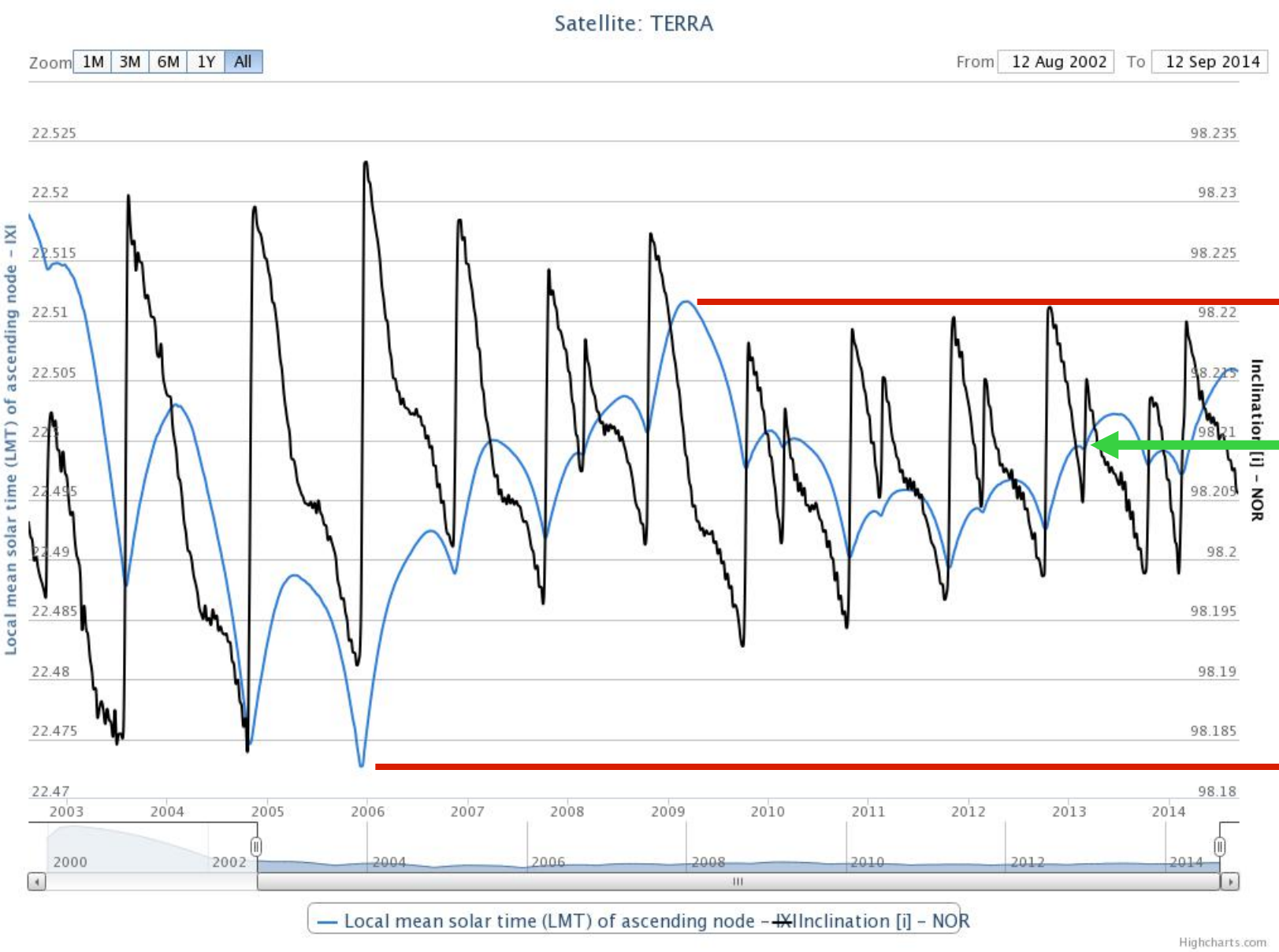
Terra Orbit Maintenance



Aqua Orbit Mantenance



Terra: Equatorial Crossing Time

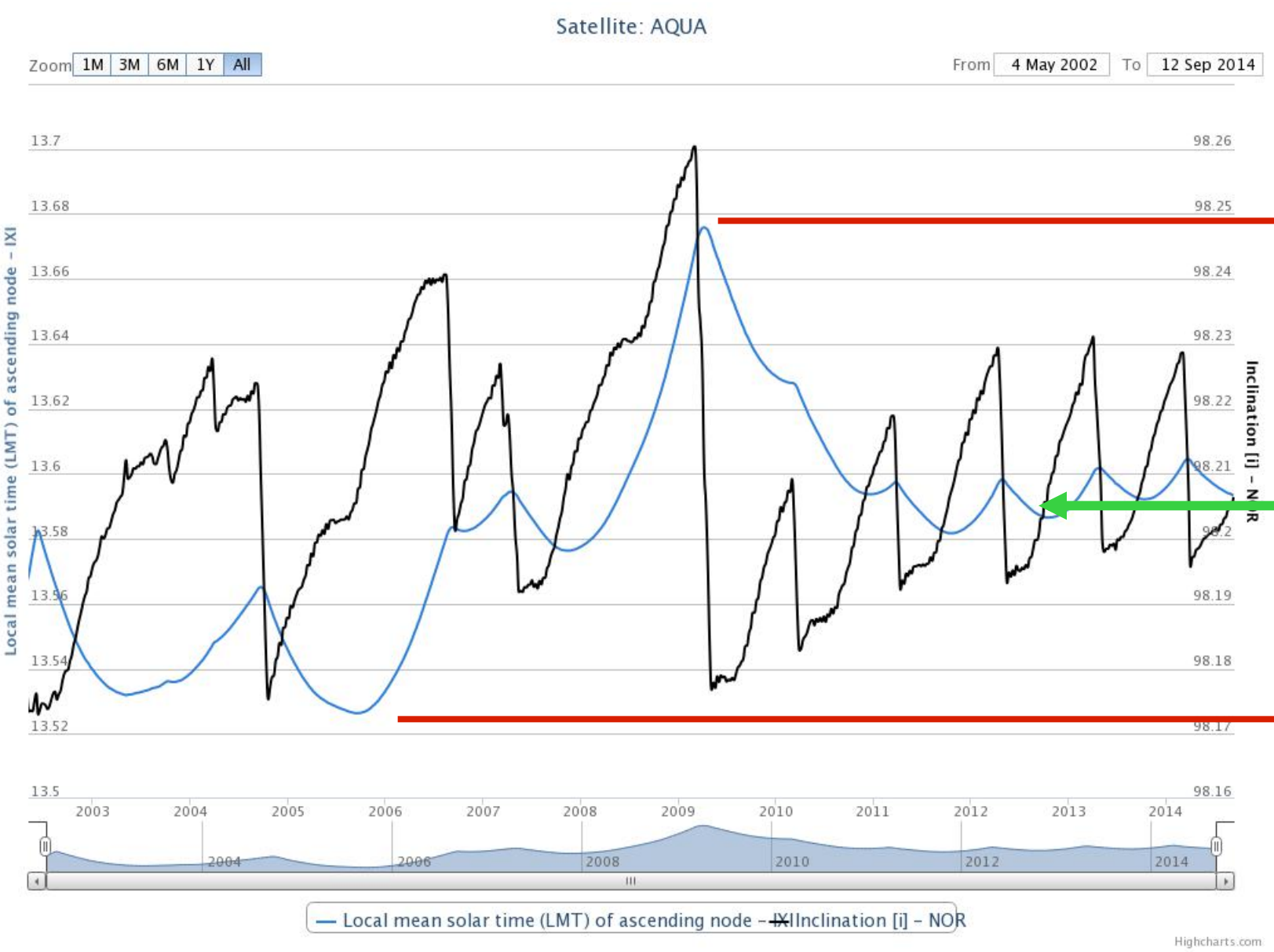


22:31

22:30

22:28

Aqua: Equatorial Crossing time



13:40

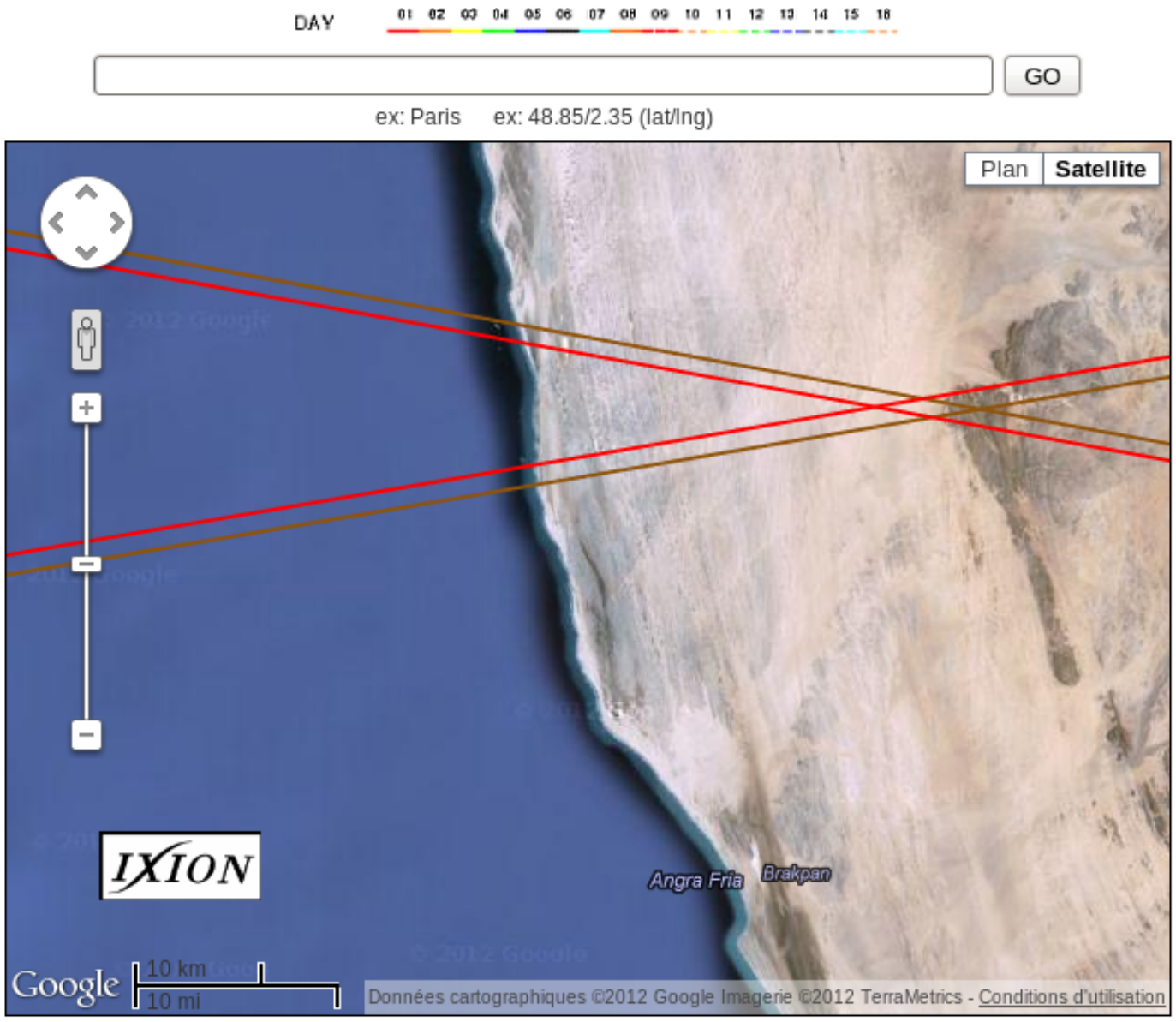
13:35

13:32

MEGHA-TROPIQUES

2012 10 18 00:00:00 UTC >>> 8.00 days
Recurrence = [14; -1; 7] 97
[NORAD] 2012 10 17 09:33:01 UTC [AscN]
REVOL. Init.: 5241 / Repr.: 5249

INCLINATION = 19.97° a = 7243.523 km
Period = 101.93 min e = 0.001111
Apogee ALTITUDE = 876 km ; Perigee ALTITUDE = 860 km;
Perigee Arg. : 93.37°



Ground-track:

Difference for
Day D
and
Day D+7

about 2 km

IXION

Attrative body

Terre

Information Cancel

Satellite

MEGHA-TROPIQUES

Norad Orbit Recurrence Annexes

Cancel

Type of display

ORBITOGRAPHY : Real Time Satellite Tracking

Cancel

Map

Google Map Carto Atlas

Google Earth

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Michel CAPDEROU
Karim RAMAGE
L.M.D. / I.P.S.L. / C.N.R.S. / U.P.M.C.

MEGHA-TROPIQUES

Date : Fri, 19 Oct 2012 13:46:12 UTC
Longitude = 0004.650° -> 14:05 LMT
Latitude = -020.052°
Altitude = 874.779 km
Satellite Speed = 7.409 km/s
Ground Track = 6.080 km/s

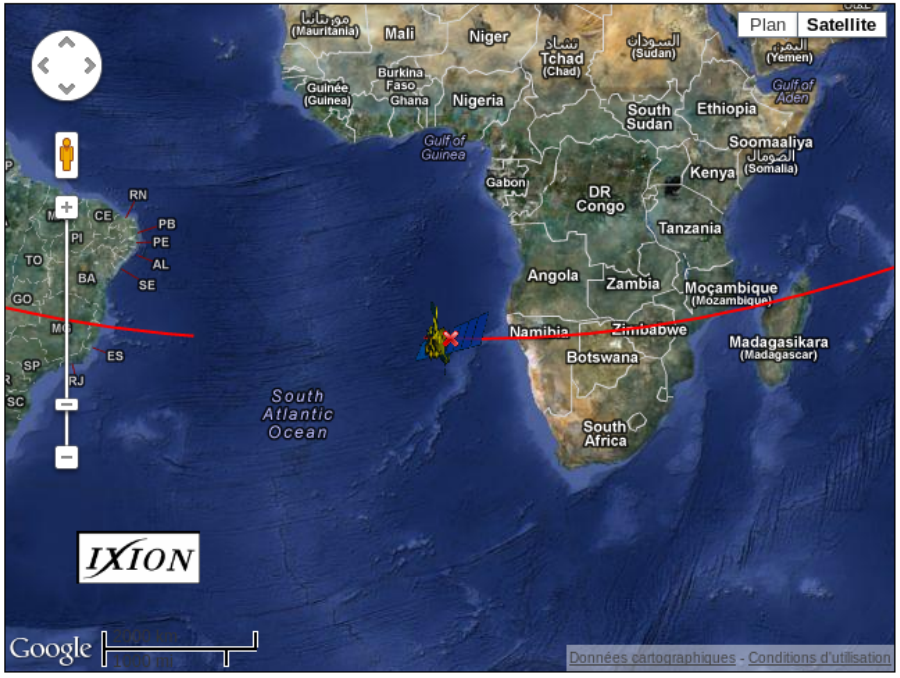
INCLINATION = 19.97° a = 7243.523 km
Period = 101.93 min e = 0.001111
Perigee Arg. : 93.37°

Satellite in day light time

☑ Keep satellite centered

☐ Draw footprint, with a step of:

☑ Draw the track of satellite



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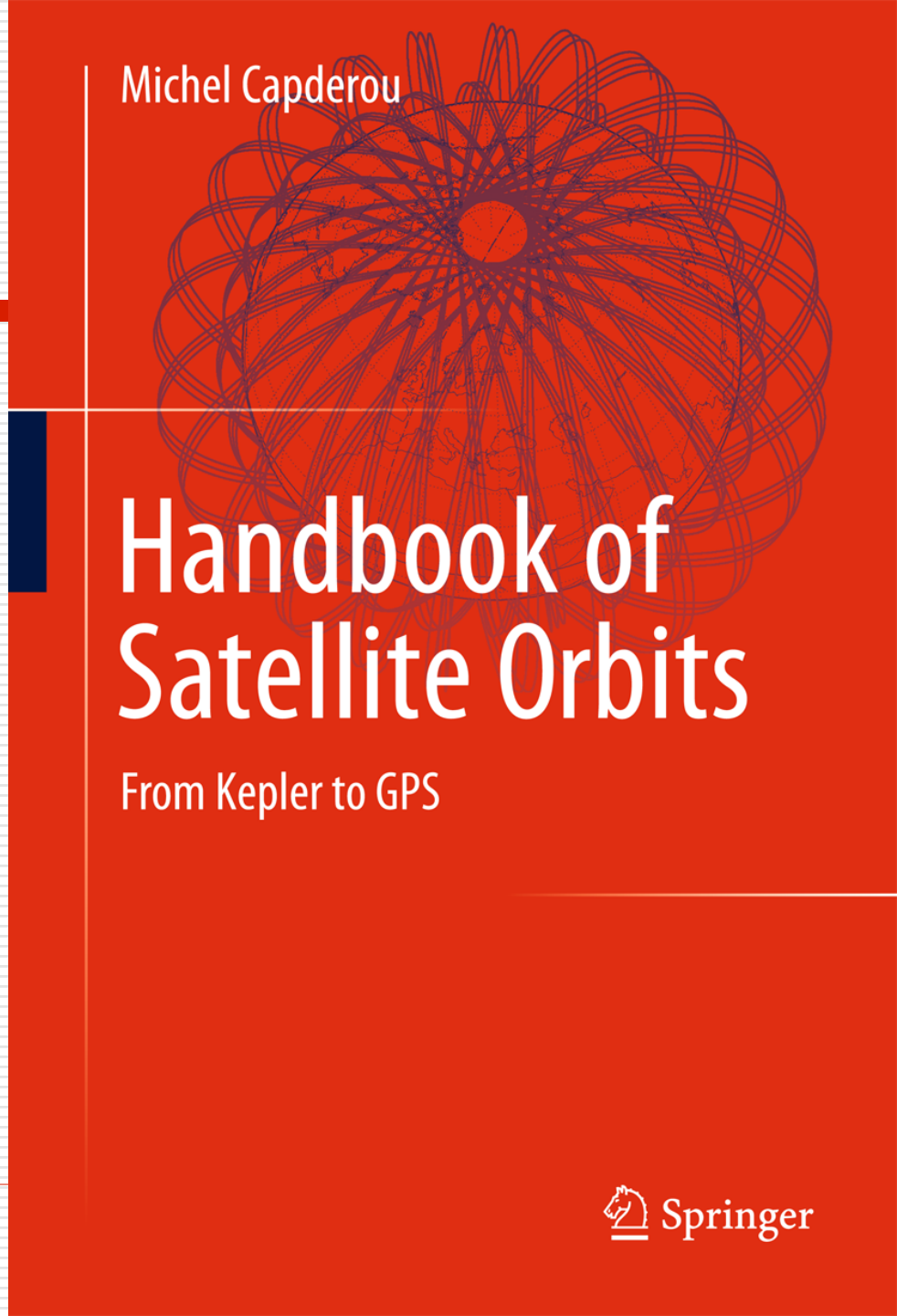
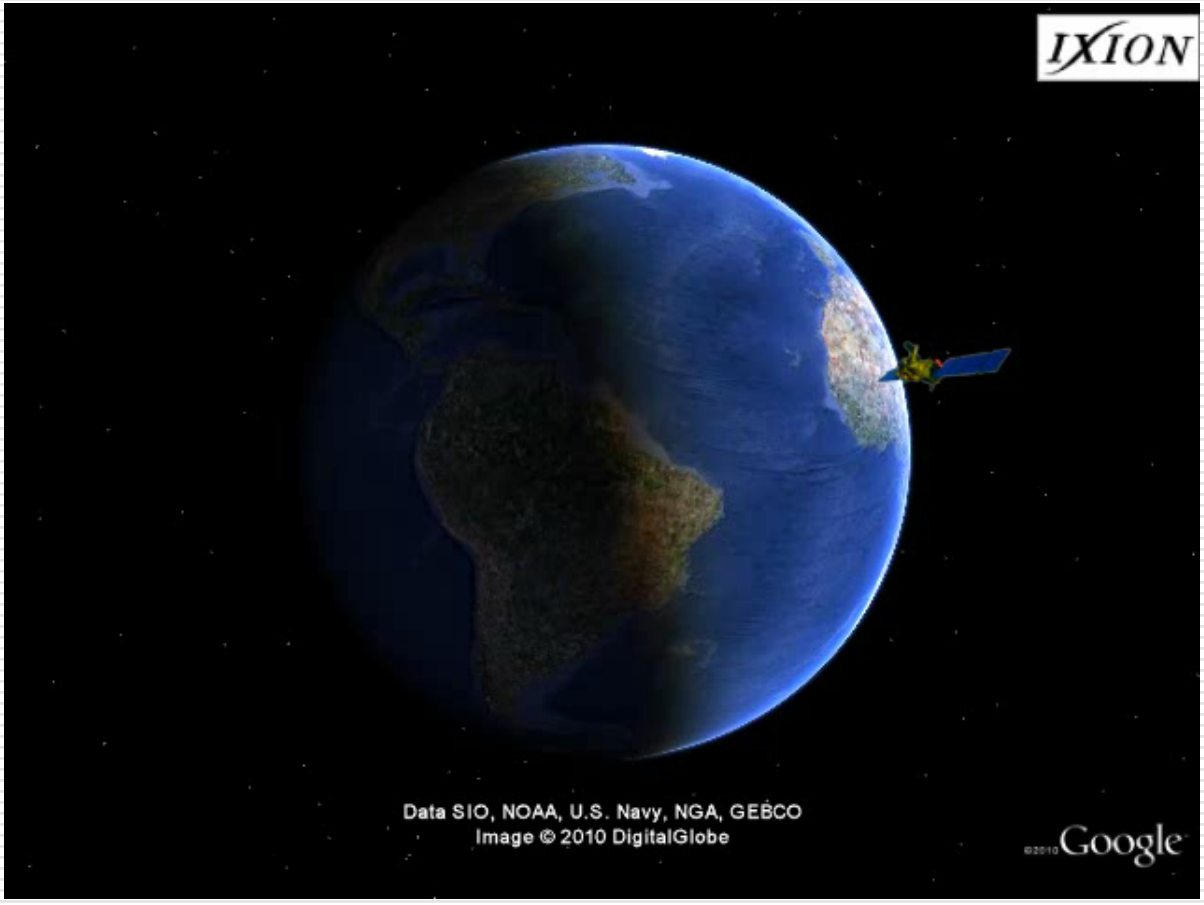
Foreword:
Charles Elachi,
JPL Director
(Jet Propulsion Laboratory
NASA / CalTech)



Appendix


IXION
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image © 2010 DigitalGlobe
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IXION
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
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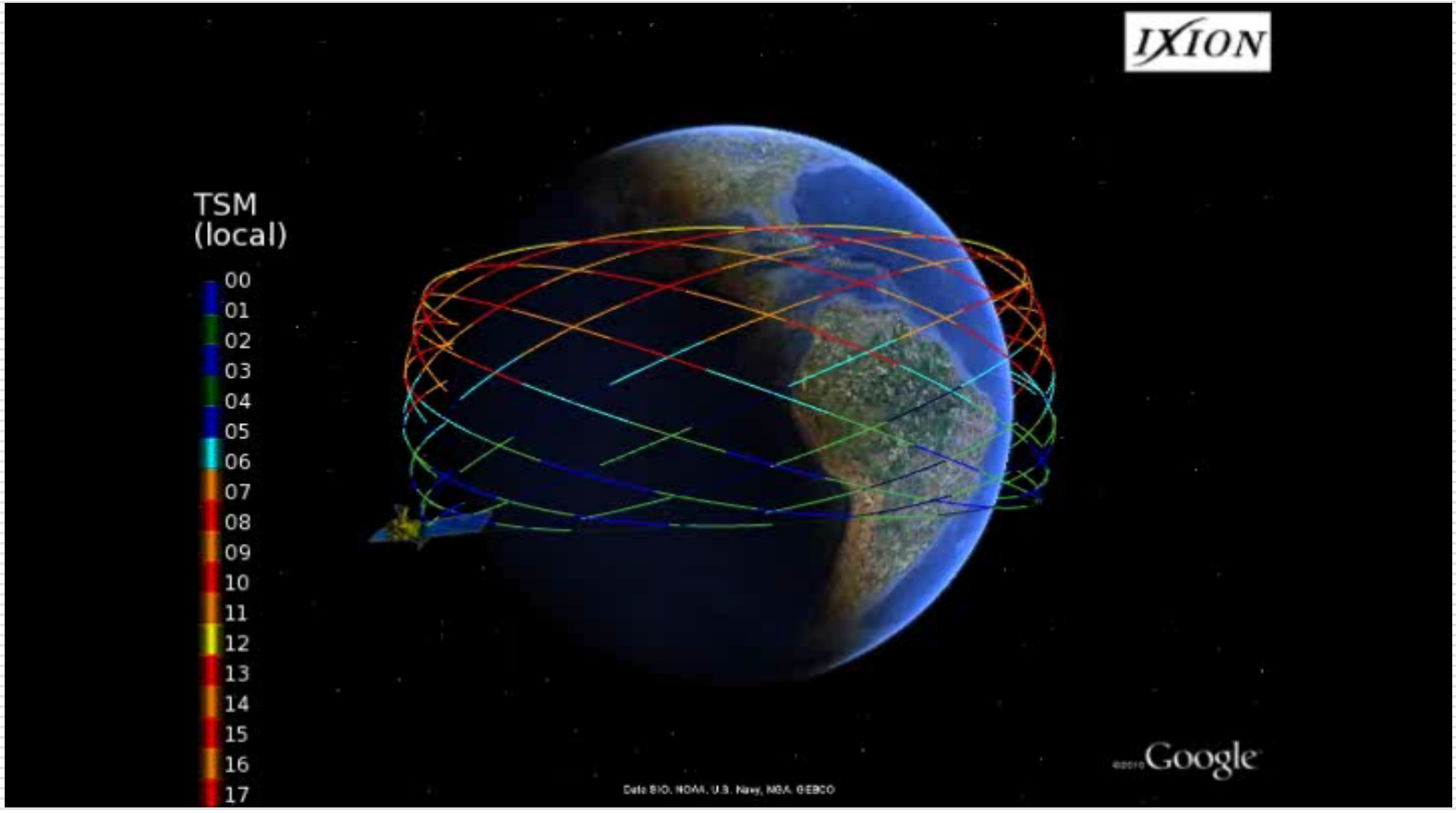
IXION
TSM
(local)
00
01
02
03
04
05
06
07
08
09
10
11
12
13
14
15
16
17
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
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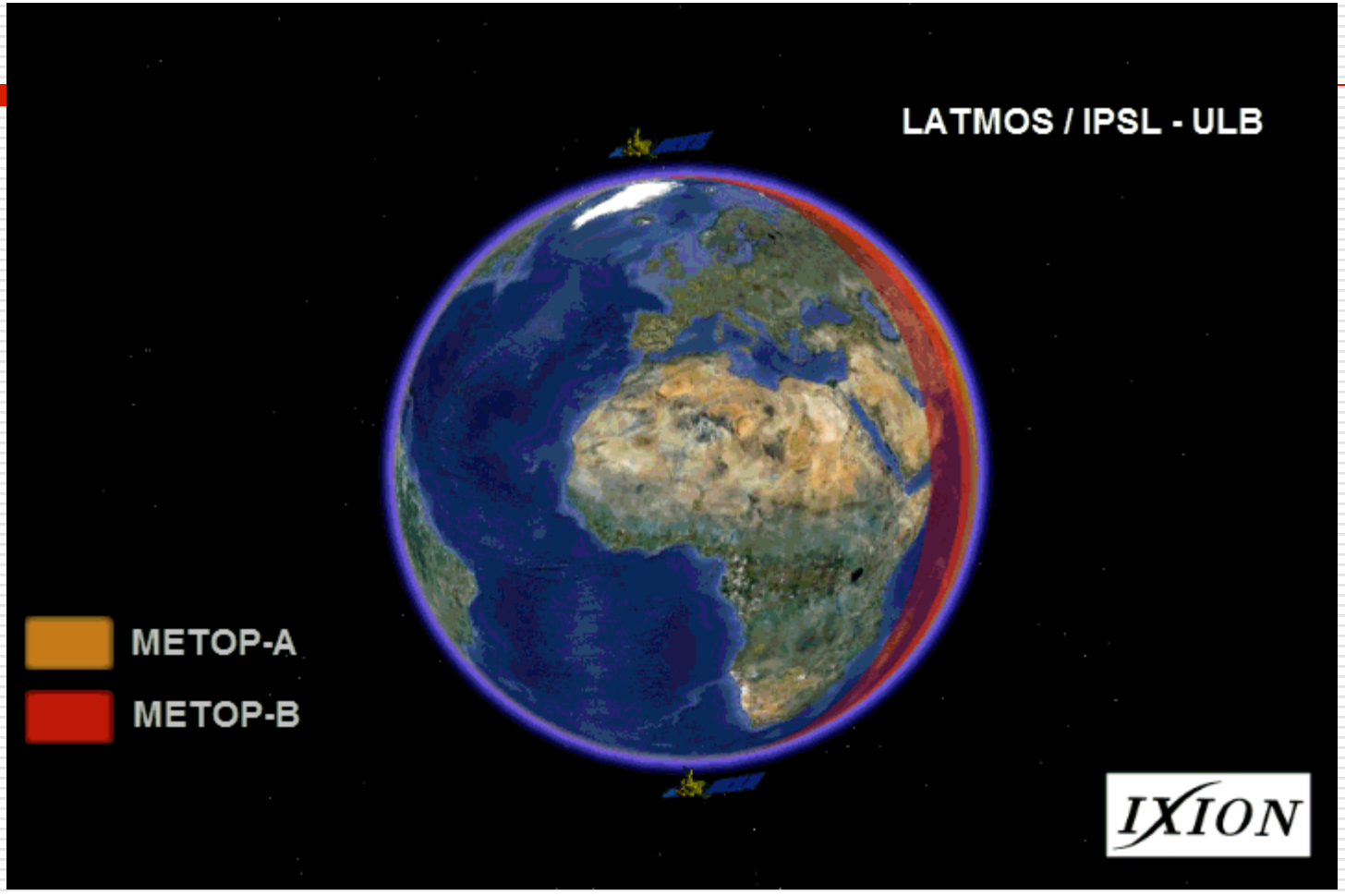
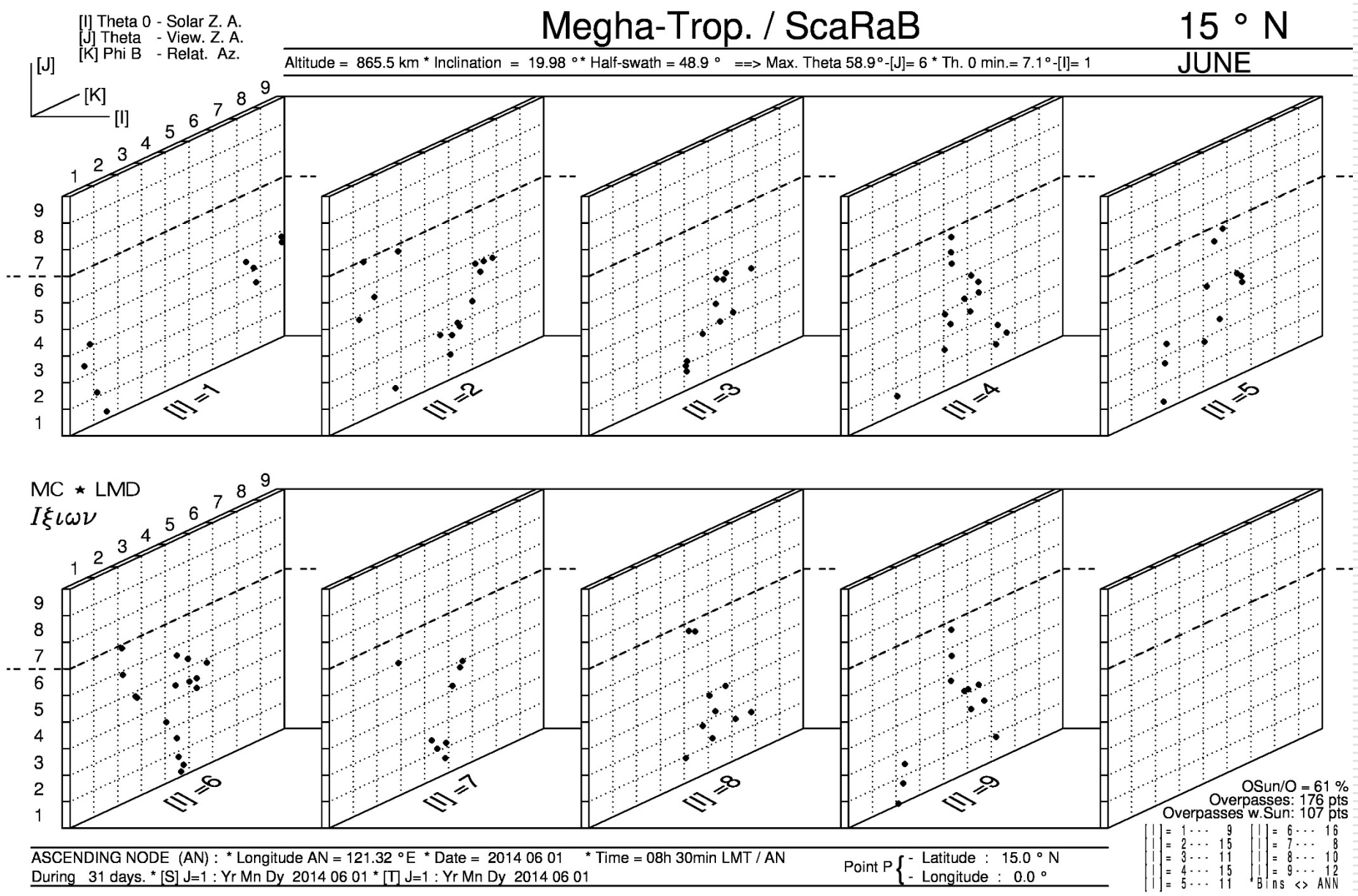

LATMOS / IPSL - ULB
METOP-A
METOP-B
IXION


[I] Theta 0 - Solar Z. A.
[J] Theta - View. Z. A.
[K] Phi B - Relat. Az.
Megha-Trop. / ScaRaB
15 ° N
Altitude = 865.5 km * Inclination = 19.98 ° * Half-swath = 48.9 ° ==> Max. Theta 58.9°-[J]= 6 * Th. 0 min.= 7.1°-[I]= 1
JUNE
[J]
[K]
[I]
[I] =1
[I] =2
[I] =3
[I] =4
[I] =5
MC ★ LMD
Ιξιων
[I] =6
[I] =7
[I] =8
[I] =9
OSun/O = 61 %
Overpasses: 176 pts
Overpasses w.Sun: 107 pts
= 1 9
= 2 15
= 3 11
= 4 15
= 5 11
= 6 16
= 7 8
= 8 10
= 9 12
Bins <> ANN
ASCENDING NODE (AN) : * Longitude AN = 121.32 °E * Date = 2014 06 01 * Time = 08h 30min LMT / AN
During 31 days. * [S] J=1 : Yr Mn Dy 2014 06 01 * [T] J=1 : Yr Mn Dy 2014 06 01
Point P - Latitude : 15.0 ° N
- Longitude : 0.0 °

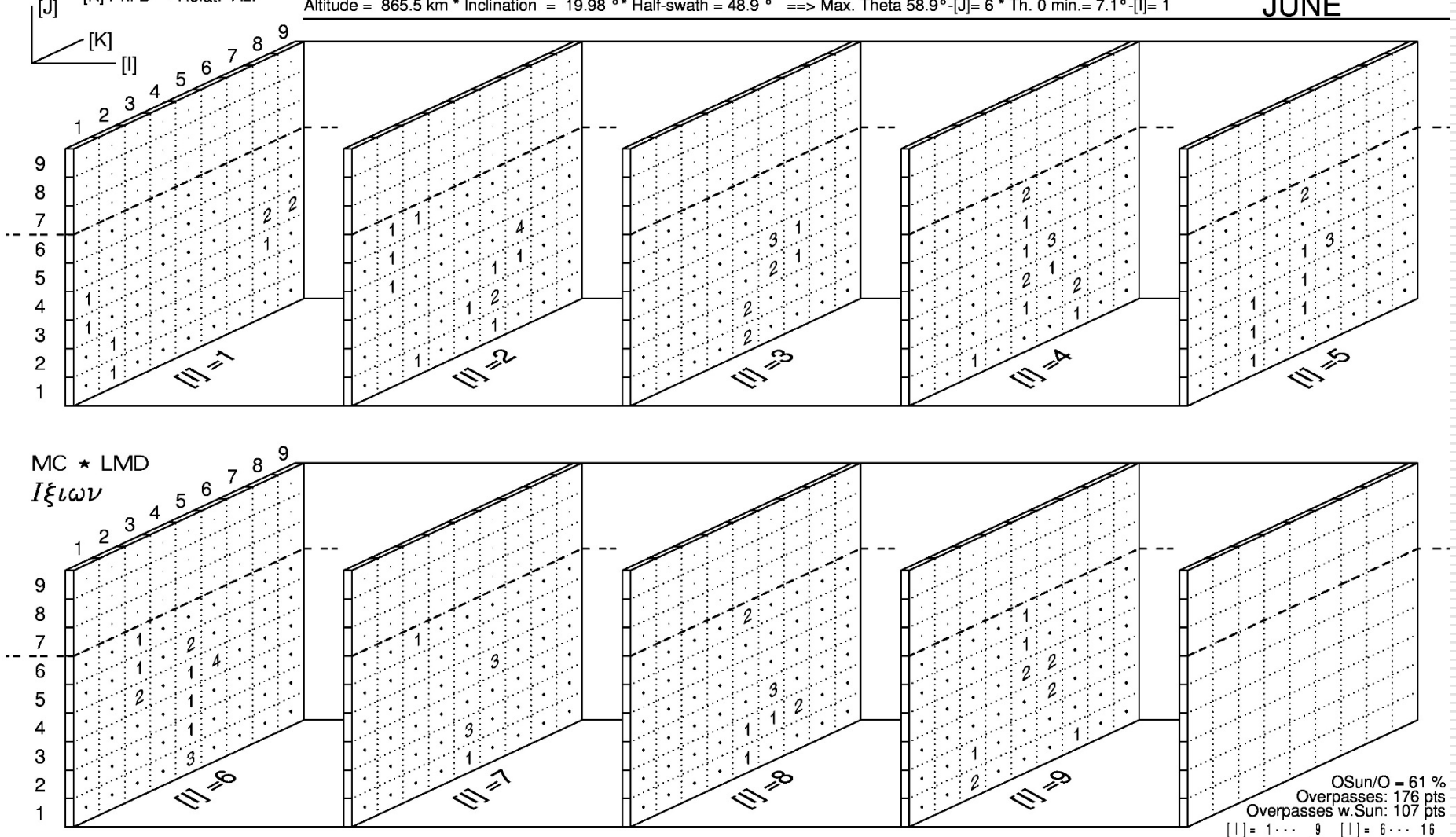
[I] Theta 0 - Solar Z. A.
[J] Theta - View. Z. A.
[K] Phi B - Relat. Az.

Megha-Tropiques / ScaRaB

15 ° N

Altitude = 865.5 km * Inclination = 19.98 ° * Half-swath = 48.9 ° ==> Max. Theta 58.9°-[J]= 6 * Th. 0 min.= 7.1°-[I]= 1

JUNE



MC ★ LMD

Ιξιων

OSun/O = 61 %
Overpasses: 176 pts
Overpasses w.Sun: 107 pts

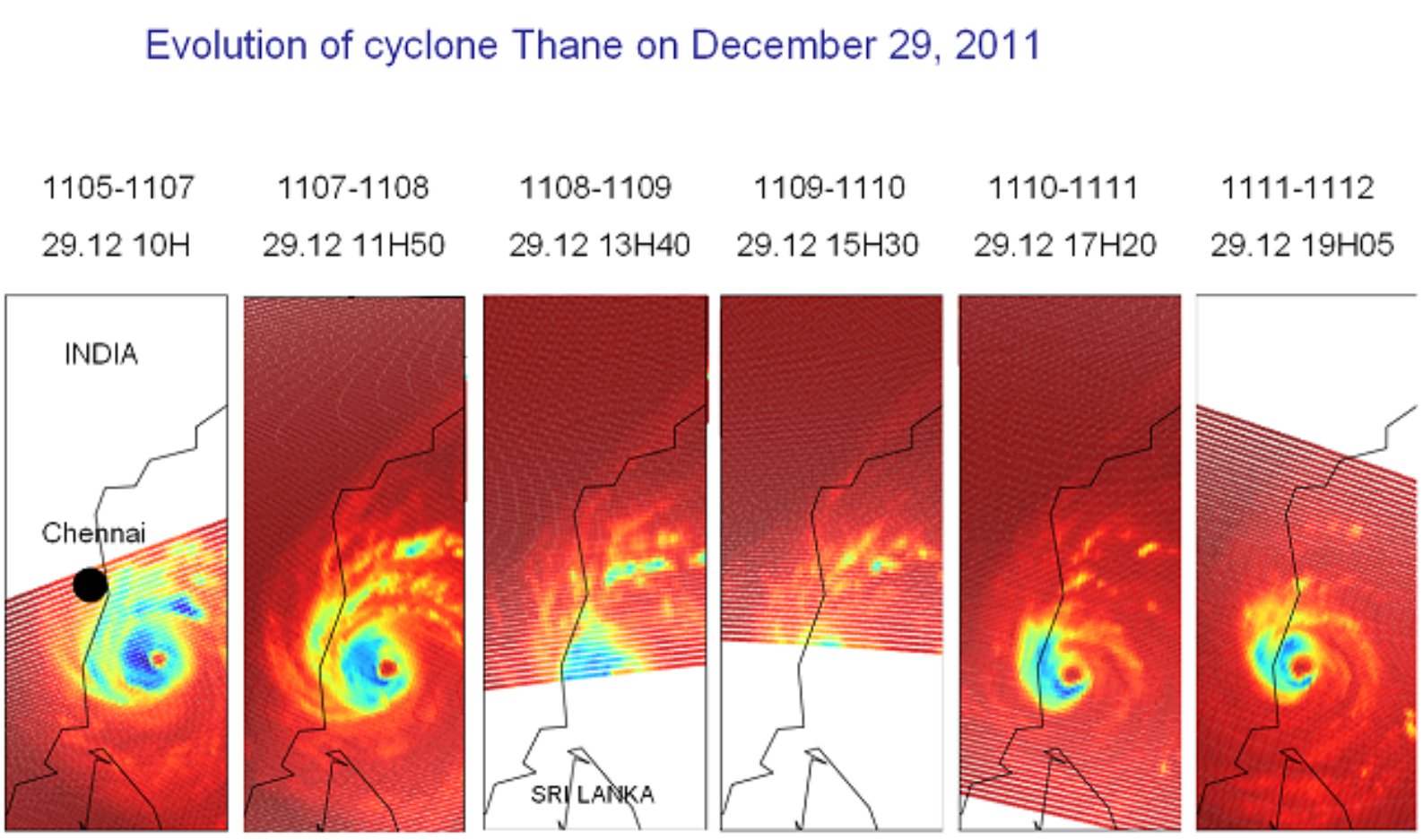
[I] = 1	9	[I] = 6	16
[I] = 2	15	[I] = 7	8
[I] = 3	11	[I] = 8	10
[I] = 4	15	[I] = 9	12
[I] = 5	11	* Bins <> ANN	

ASCENDING NODE (AN) : * Longitude AN = 121.32 °E * Date = 2014 06 01 * Time = 08h 30min LMT / AN

During 31 days. * [S] J=1 : Yr Mn Dy 2014 06 01 * [T] J=1 : Yr Mn Dy 2014 06 01

Point P { - Latitude : 15.0 ° N
- Longitude : 0.0 °

6 consecutive overpasses



Instrument SAPHIR

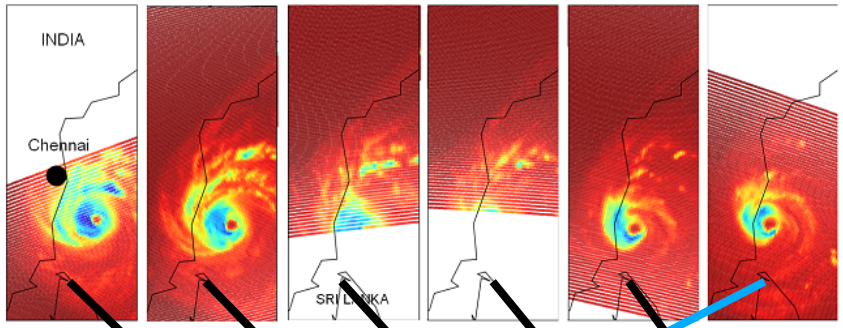
Cycle / Phasage = 7 jours [14; -1; 7] 97
Cycle / Soleil = 51 jours (Cs= -51.3)
* J=1 (An Mo Jr)* [T] 2011 12 01

Megha-Tropiques

12 ° N

TABLEAU MENSUEL

INITIALISATION [NORAD] NOEUD ASCENDANT (NA) : * Longitude NA = 143.70 °E * Date = 2011 12 29 * Instant = 14h 34min TSM / NA



TSM 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

[T] : Trace

PASSAGES (n = 166)
DU SATELLITE S [EIGEN-C3]
POUR LE POINT P
- Latitude : 12.0 ° N
- Longitude : 80.0 ° E
Pour P : TUC = TSM - 05h 20m

CHAMP DE VUE : 85.9 °

(1) (2) DIRECTION P-S
△ ASC ▼ DES

Sens trigonom. direct.

- Angle zénithal (dans le plan perpendiculaire à la trace). (1)

- Azimut (dans le plan horizontal local) par rapport au Nord. (2)

ORBITE a = 7243.615 km
Altitude = 865.5 km
Inclinaison = 19.98 °
Décalage équat. = 2892.0 km
Période = 101.93 min
Moyen mvt = 14.13 tours/j

BALAYAGE
Demi-fauchée = 43.0 °
Ang.Zénithal maximal = 50.7 °
D.-fauchée sol = 862.8 km
Fr. Recouvrement équat. = 1.628
Latit. max. atteinte = 27.7 °

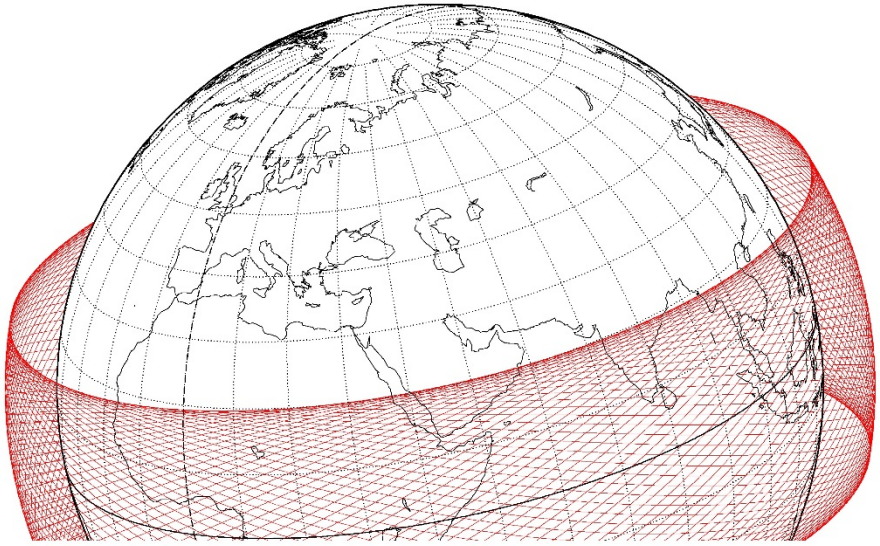
Ιξιων
MC ★ LMD

NORAD
Two-line Elements (TLE)

- a — semi-major axis
- i — inclination
- e — eccentricity
- Ω, ω, M — angles
- n — number of revolutions per day

- i, e and angles are given directly by TLE
- By an iterative method (perturbed equations of motion), we obtain the value of a
- h — equivalent altitude: $h = a - R$
  R = Earth equatorial radius

Comparison with the Sun-Synchronous satellites



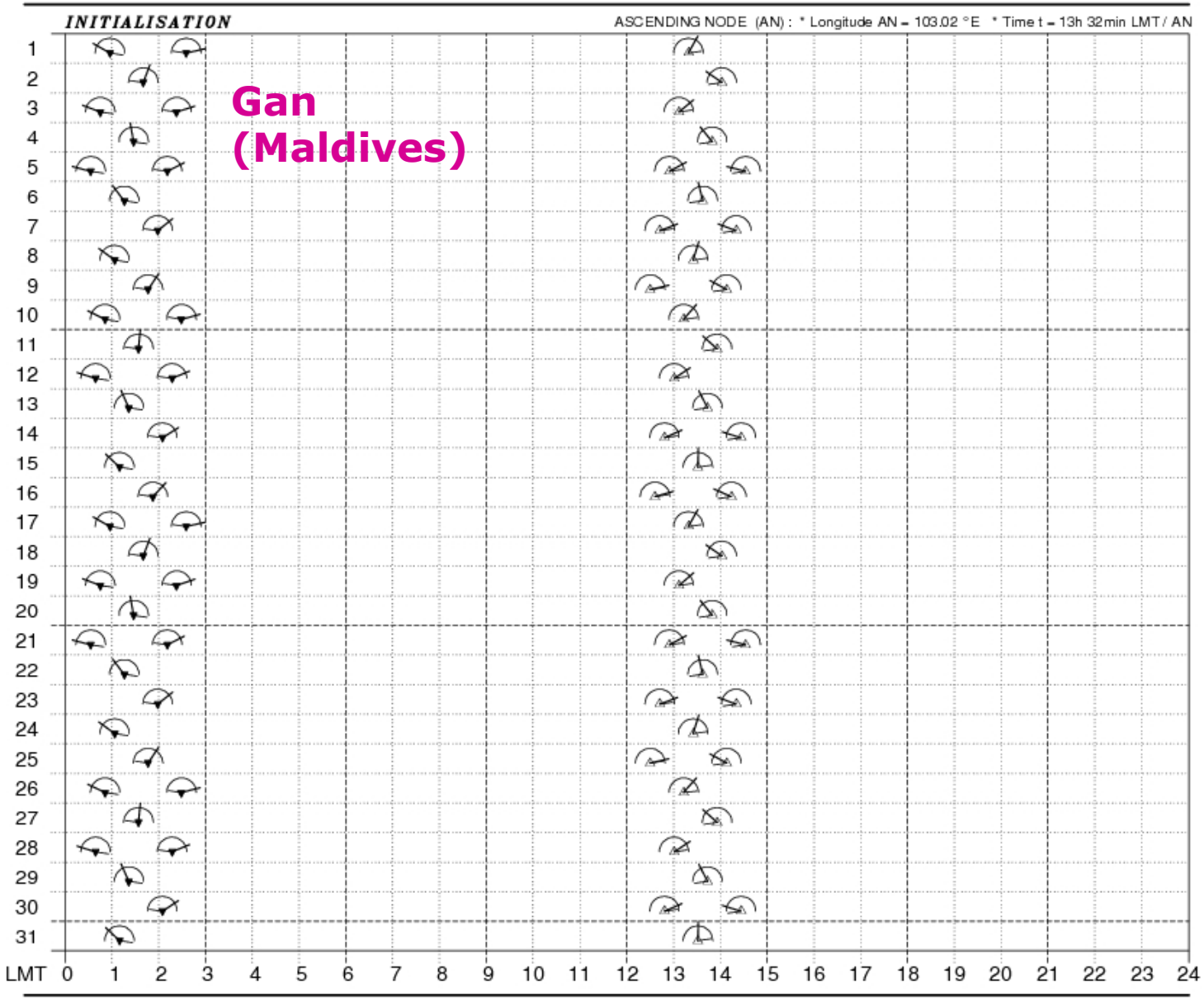
X

Recurrence cycle = 16 days [15; -7; 16] 233
Precession cycle: infinity (SUN-S.)
***

Aqua / CERES

0 °

MONTHLY TABLE



OVERPASSES (n = 81)
OF SATELLITE S [EGM96]
FOR POINT P
- Latitude : 0.0 °
- Longitude : 75.0 ° E
For P: UTC = LMT - 05h 00m

FIELD OF VIEW : 123.6 °

(1) (2) P-S DIRECTION
△ ASC ▼ DES

Right-handed system
- Zenith angle (in the plane orthogonal to the track). (1)
- Azimuth (in the local horizontal plane) with respect to the North. (2)

ORBIT a = 7077.736 km
Altitude = 699.6 km
Incl. / Sun-s. = 98.21 °
Equatorial shift= 2751.9 km
Period = 98.88 min
Mean mot. = 14.56 rev/day

SCANNING
Half-swath = 61.8 °
Maximal zenith angle = 78.0 °
H.-swath (ground) = 1801.2 km
Equatorial overlap = 1.336
Max. attained latit. = 90.0 °
Latit. overlap:82.0° <--> 90.0°

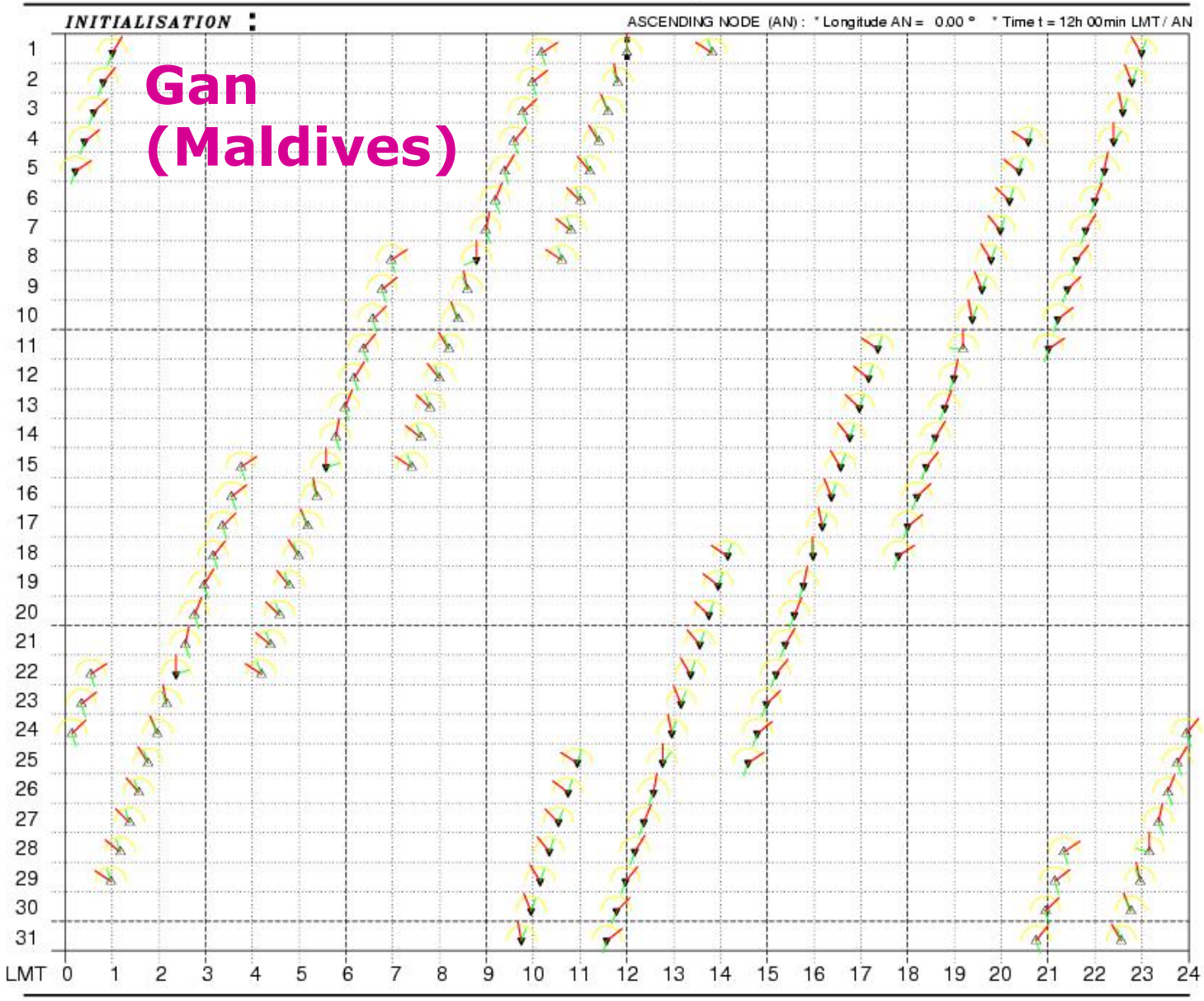
Ιξιων
MC ★ LMD

Recurrence cycle = 7 days [14; -1; 7] 97
Precession cycle= 51 days (Cs= -51.3)
***

Megha-Trop. / ScaRaB

0 °

MONTHLY TABLE



OVERPASSES (n = 136)
OF SATELLITE S [GEM-T2]
FOR POINT P
- Latitude : 0.0 °
- Longitude : 0.0 °
For P: UTC = LMT + 00h 00m

FIELD OF VIEW : 97.8 °

(1) (2) P-S DIRECTION
△ ASC ▼ DES

Right-handed system

- Zenith angle (in the plane orthogonal to the track). (1)

- Azimuth (in the local horizontal plane) with respect to the North. (2)

ORBIT a = 7243.700 km
Altitude = 865.6 km
Inclination = 20.00 °
Equatorial shift= 2892.0 km
Period = 101.93 min
Mean mot. = 14.13 rev/day

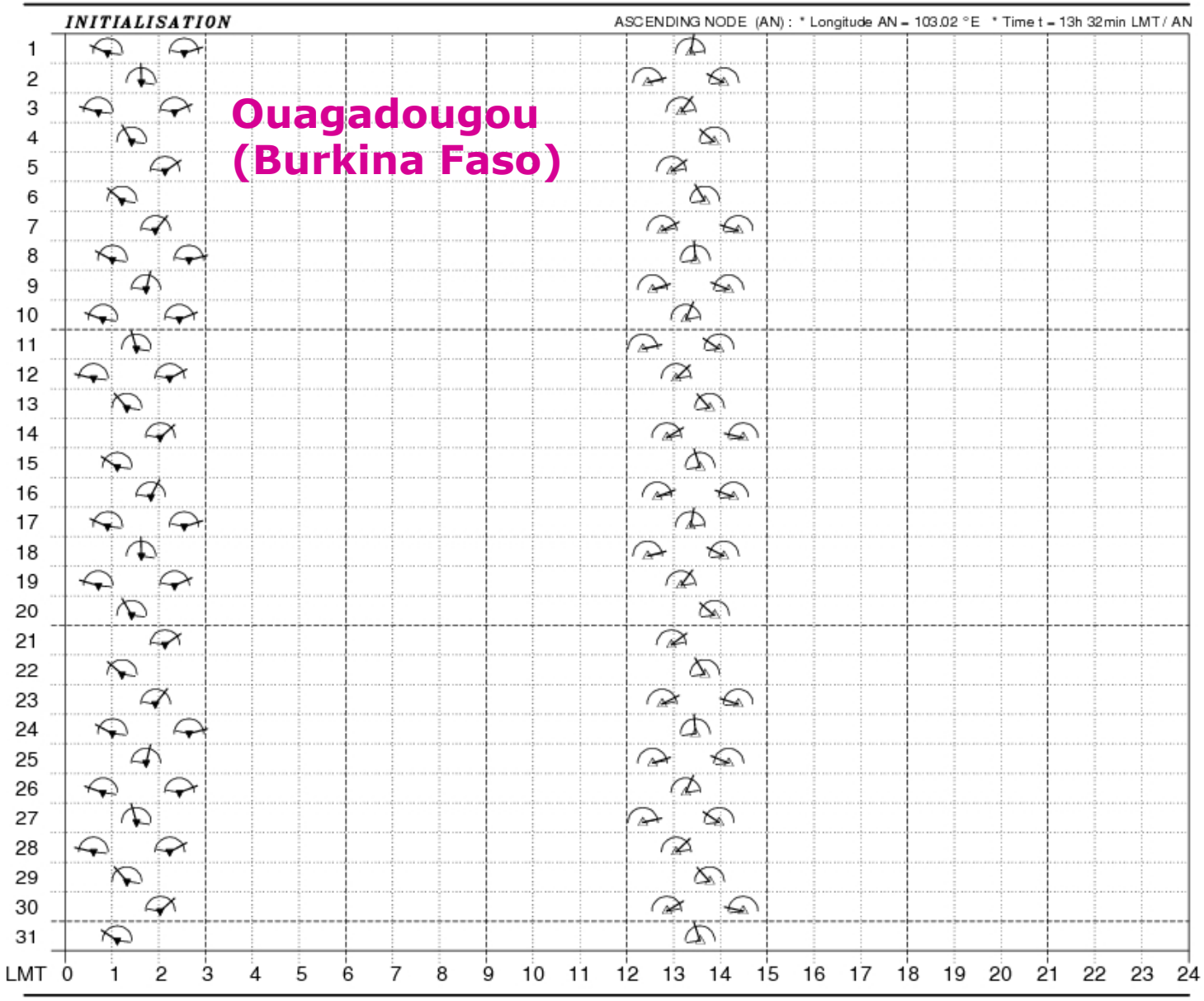
SCANNING
Half-swath = 48.9 °
Maximal zenith angle = 58.9 °
H.-swath (ground) = 1108.3 km
Equatorial overlap = 2.089
Max. attained latit. = 30.0 °

Ιξιων
MC ★ LMD

Recurrence cycle = 16 days [15; -7; 16] 233
Precession cycle: infinity (SUN-S.)
***

Aqua / CERES

10 ° N MONTHLY TABLE



OVERPASSES (n = 83)
OF SATELLITE S [EGM96]
FOR POINT P
- Latitude : 10.0 ° N
- Longitude : 75.0 ° E
For P: UTC = LMT - 05h 00m

FIELD OF VIEW : 123.6 °

(1) (2) P-S DIRECTION
△ ASC ▼ DES

Right-handed system
- Zenith angle (in the plane orthogonal to the track). (1)
- Azimuth (in the local horizontal plane) with respect to the North. (2)

ORBIT a = 7077.736 km
Altitude = 699.6 km
Incl. / Sun-s. = 98.21 °
Equatorial shift= 2751.9 km
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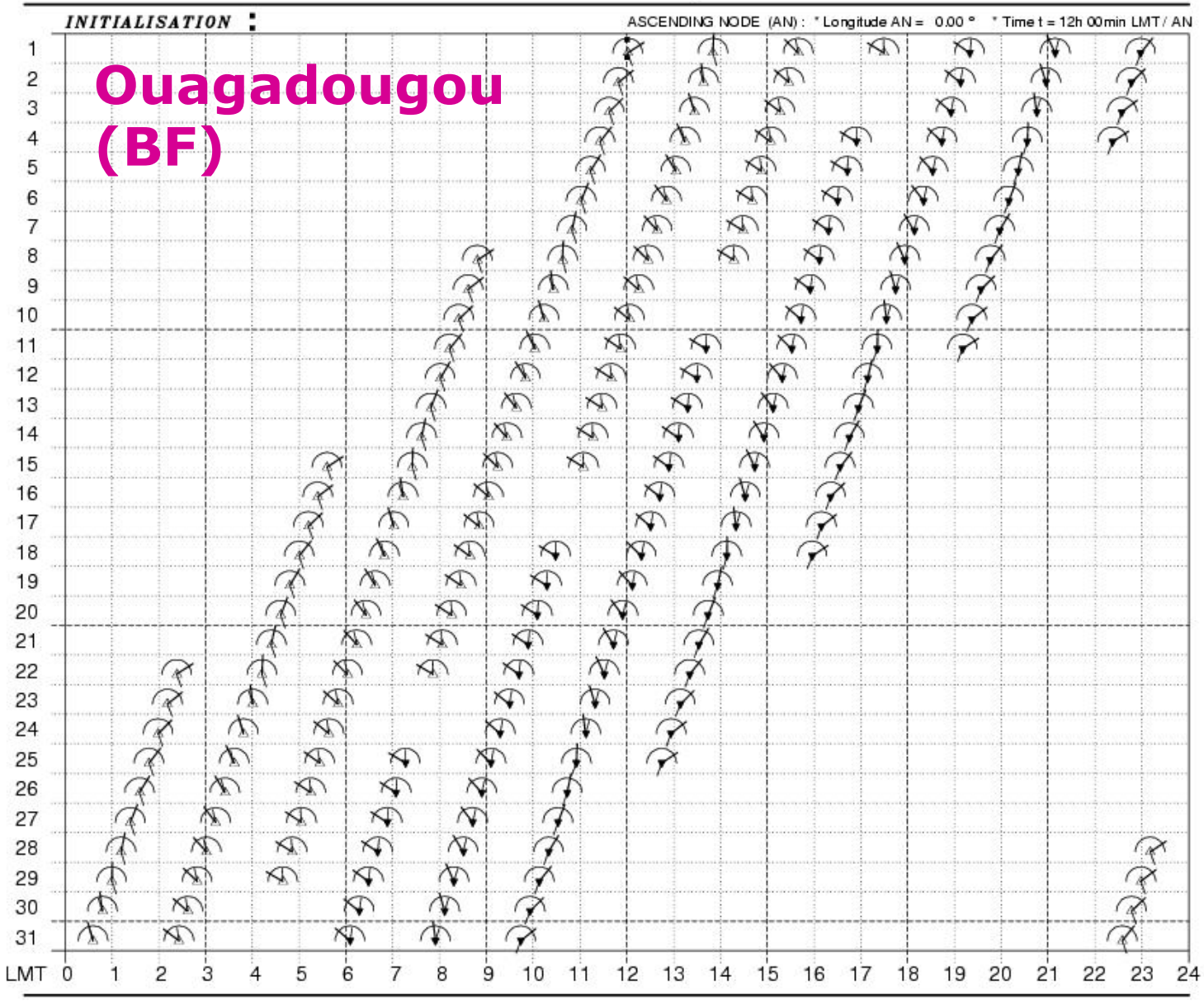
Max. attained latit. = 90.0 °
Latit. overlap:82.0° <--> 90.0°

Ιξιων
MC ★ LMD

Recurrence cycle = 7 days [14; -1; 7] 97
Precession cycle= 51 days (Cs= -51.3)
***

Megha-Trop. / ScaRaB

10 ° N MONTHLY TABLE



OVERPASSES (n = 196)
OF SATELLITE S [GEM-T2]
FOR POINT P
- Latitude : 10.0 ° N
- Longitude : 0.0 °
For P: UTC = LMT + 00h 00m

FIELD OF VIEW : 97.8 °

(1) (2) P-S DIRECTION △ ASC ▼ DES

Right-handed system

- Zenith angle (in the plane orthogonal to the track). (1)
- Azimuth (in the local horizontal plane) (2) with respect to the North.

ORBIT a = 7243.700 km
Altitude = 865.6 km
Inclination = 20.00 °
Equatorial shift= 2892.0 km
Period = 101.93 min
Mean mot. = 14.13 rev/day

SCANNING
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Maximal zenith angle = 58.9 °
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Ιξιων
MC ★ LMD