The MT Orbit: Consequence for Earth Radiation Studies

Earth Radiation Budget Workshop 2014 - Toulouse, France

Tuesday, October 7

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Megha-Tropiques
Orbit - ref.: Earth

Recurrence = [14; -1; 7] 97

Time span shown: 7.00 days

Altitude = 865.5 km
Inclination = 20.00 °
Period = 101.93 min * rev/day = 14.13
Equat. orbital shift = 2892.0 km (26.0 °)

Projection: Orthographic
Property: none
_aspect: Oblique
\[ T:Azimuthal - Graticule: 10° \]

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

\[ Iξων\]
\[ MC \star LMD\]
\[ Απλας\]
MT : A unique example for LEO satellites, with $i = 20^\circ$

- $i = 20^\circ$ MT
- $i = 35^\circ$ TRMM
- $i = 40^\circ$ GPM – LIO
- $i = 65^\circ$ GPM – core
- $i = 66^\circ$ Jason
- $i = 98^\circ$ Sun-synchronous
Satellite Altitude : $h = 866$ km.

**MT Orbit**

**Inclination :** $i = 20^\circ$

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)
- 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)
Monthly table

For a given location

Day

1

2

31

Hour, LMT (Local Mean Solar Time)

<table>
<thead>
<tr>
<th>Day</th>
<th>Hour, LMT</th>
</tr>
</thead>
<tbody>
<tr>
<td>31</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>x</td>
</tr>
<tr>
<td>2</td>
<td>x</td>
</tr>
</tbody>
</table>

← indication of the overpasses
Recurrence cycle = 7 days [14; -1; 7] 97
Precession cycle = 51 days (C= -51.3)

Megha-Trop. / ScaRaB

**INITIALISATION:**

<table>
<thead>
<tr>
<th>J = 1</th>
</tr>
</thead>
</table>

ASCENDING NODE (AN):
- Longitude AN = 0.00°
- Time t = 12h 00min LMT / AN

**Precession cycle**

12 hr ↔ 26 day

**FIELD OF VIEW:** 97

**OVERPASSES (n = 136)**

<table>
<thead>
<tr>
<th>FOR POINT P</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Latitude: 0.0°</td>
</tr>
<tr>
<td>- Longitude: 0.0°</td>
</tr>
</tbody>
</table>

For P: UTC = LMT + 00h 00min

**ORBIT**

- Area (a = 724.3)
- Altitude = 865.6 km
- Inclination = 20.00°
- Equatorial shift = 2892.0 km
- Period = 101.93 min
- Mean motion = 14.13 rev/day

**SCANNING**

- Half-swath = 48.9°
- Maximal zenith angle = 58.9°
- Horizontal swath = 1108.3 km
- Equatorial overlap = 2.096 km
- Max. attained lat = 30.0°
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
**Aqua / CERES**

**INITIALISATION**

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**ASCENDING NODE (AN)**: *Longitude AN = 103.02° E*  
*Time t = 13h 32min LMT / AN*

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**MT**

**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°

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**Sun-synchronous satellite**

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**SCANNING**
- **H-alt swath = 61.8°**  
- **Maximal zenith angle = 78.0°**  
- **H-swath (ground) = 18012 km**  
- **Equatorial overlap = 1336**  
- **Max. attained lat. = 50.0°**  
- **Latt. overlap: 82.0° <-> 90.0°**

---

**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)
Sun-Target-Satellite Geometry

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

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

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

\[
\begin{align*}
\text{SZA: } &0^\circ \text{ to } 90^\circ \rightarrow \text{ Bin I: } 1 \text{ to } 9 \\
\text{VZA: } &0^\circ \text{ to } 90^\circ \rightarrow \text{ Bin J: } 1 \text{ to } 9 \\
\text{RAA: } &0 \text{ to } 180^\circ \rightarrow \text{ Bin K: } 1 \text{ to } 9
\end{align*}
\]
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°)
\[(5, 4, 2)\]

\[I = 5\]

\[J = 4\]

\[K = 2\]
Sampling for the Tropical Zone
Megha-Tropiques
Orbit - ref.: Earth

Recurrence = [14; -1; 7] 97

Altitude = 865.5 km
Inclination = 20.00 °
Period = 101.93 min  * rev/day = 14.13
Equiv. orbital shift = 2892.0 km (26.0 °)

Time span shown: 1440.0 min = 1.00 day

Projection: Orthographic
Project. centre: 26.0 ° N; 46.0 ° E
Asc. Node: 0.00 °

Property: none
Aspect: Oblique

Ω T.: Azimuthal - Graticule: 10°

α [4.2] [-90.0/ +64.0/ +44.0] [+12] EIGEN-C3
Megha-Tropiques / ScaRaB
Orbit - ref.: Earth

Recurrence = [14; -1; 7] 97

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

Across track swath (XT mode)

Altitude = 865.5 km
Inclination = 20.00 °
Period = 101.93 min * rev/day = 14.13
Equat. orbital shift = 2892.0 km (26.0 °)
** Half-swath: 48.9° => 1108 km [0.75 min]
Megha-Tropiques

INITIALISATION:

ASCENDING NODE (AN): * Longitude AN = 0.00 ° * Time t = 12h 00min LMT / AN

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 °

P.S DIRECTION
ASC △ DES

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 = 7243.677 km
Altitude = 865.5 km
Inclination = 20.00 °
Equatorial shift = 2882.0 km
Period = 101.93 min
Mean mot. = 14.13 revisit

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 °

ǐsòv
MC ★ LMD
Reccurrence cycle = 7 days [14; -1; 7] 97
Precess. cycle = 51 days (C= 51.3)

Megha-Tropiques

ASCENDING NODE (AN) : Longitude AN = 0.00 ° * Time t = 12h 00min LMT / AN

INITIALISATION :

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) P-S DIRECTION
△ ASC ▼ DES
Right-handed system
- Zenith angle (in
the piano orthogonal
to the track).
- Azimuth (in the
local horizontal plane)
with respect to the North.

ORBIT a = 7243.677 km
Altitude = 665.5 km
Inclination = 20.00 °
Equatorial shift= 2892.0 km
Period = 101.93 min
Mean mot. = 14.13 revisit 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 °

Iξων
MC ★ LMD
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 + 0h 00m

FIELD OF VIEW: 97.8 °

P.S DIRECTION
△ ASC ▼ DES
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 = 7243.677 km
Altitude = 665.5 km
Inclination = 20.00 °
Equatorial shift = 2992.0 km
Period = 101.93 min
Mean mot. = 14.13 reviday

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

Iξων
MC ★ LMD
**Megha-Tropiques**

**INITIALISATION:**

ASCENDING NODE (AN): * Longitude AN = 0.00° * Time t = 12h 00min LMT / AN

**OVERPASSES (n = 177)**

**OF SATELLITE S [EGM2008]**

**FOR POINT P**
- Latitude : 15.0° N
- Longitude : 0.0°

For P. UTC = LMT + 0h 00m

**FIELD OF VIEW:** 97.8°

**(1)** P–S DIRECTION
△ ASC ▼ DES

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

**ORBIT** $a = 7243.677$ km

Altitude = 665.5 km
Inclination = 20.00°
Equatorial shift = 2892.0 km
Period = 101.93 min
Mean mot. = 14.13 reviday

**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°

$\xi_\omega$

MC ★ LMD
**Megha-Tropiques**

INITIALISATION:

ASCENDING NODE (AN): * Longitude AN = 0.00 ° * Time t = 12h 00min LMT / AN

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 + 0h 00m

FIELD OF VIEW: 97.8 °

(1) P-S DIRECTION
△ ASC ▼ DES

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 = 7243.677 km
Altitude = 865.5 km
Inclination = 20.00 °
Equatorial shift = 2892.0 km
Period = 101.93 min
Mean mot. = 14.13 reviday

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 °

Iκεων
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

Recurrence = [14; -1; 7] 97

Time span shown: 100.0 min = 0.07 day

Ground track - Conical swath / VZA=53.1°

Altitude = 865.5 km
Inclination = 20.00 °
Period = 101.93 min * rev/day = 14.13
Equat. orbital shift = 2892.0 km (26.0 °)

** Half-aperture: 65.0 ° - Radius/grnd 928 km [0.25 min]
** Effect. h-ap.: 42.3 ° => 841 km - Effect. swath: 1682 km
Megha-Tropiques / ScaRaB
Orbit - Ground track

Recurrence = [14; -1; 7] 97

>>> Time span shown: 100.0 min = 0.07 day
Across track swath (XT mode)

Altitude = 865.5 km   a = 7243.678 km
Inclination = 20.00 °
Period = 101.93 min  * rev/day = 14.13
Equate. orbital shift = 2892.0 km (26.0 °)
** Half-swath: 48.9 ° => 1108 km [0.25 min]
Mean number of overpasses
Megha-Tropiques and Terra Rendez-vous
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

Altitude = 865.5 km
Inclination = 19.98 °
Period = 101.93 min
*rev/day = 14.13

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

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

Projection: Mercator
Project. centre: 0.0 ° ; 105.0 ° E

Property: Conformal
Aspect: Direct
[NORAD] Revolution: 2581

T.:Cylindrical - Graticule: 10°
{4.2} [ +90.0/ +0.0/+165.0] [-] EIGEN-C3
[NORAD] 2012 04 12 02:39:35 UTC

Δλας
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 Maintenance
MT: a very accurate Orbit Maintenance
Equivalent altitude: \( h = a - R \)
Terra Orbit Maintenance

Satellite: TERRA

Equivalent altitude \([h = a - \text{Requatoria}] + 1X1\)

From 2 Apr 2000 To 12 Sep 2014

200 meters
Aqua Orbit Maintenance

Satellite: AQUA

From 10 Aug 2002 To 9 Sep 2014

Equivalent altitude [h = a - Requatorial] - IXI

200 m
Terra: Equatorial Crossing Time

Satellite: TERRA

From 12 Aug 2002 To 12 Sep 2014

Local mean solar time (LMT) of ascending node - Inclination [i] - NOR

22:30

22:31

22:28
Ground-track:

Difference for Day D and Day D+7 about 2 km
MEGHA-TROPIQUES

Date : Fri, 19 Oct 2012 13:46:12 UTC
Longitude = 0004.650°
Latitude = -020.052°
Altitude = 874.779 km
Satellite Speed = 7,409 km/s
Ground Track = 6,080 km/s

INCLINATION = 19.97°
Period = 101.93 min
Perigee Arg. = 93.37°
a = 7,243.523 km
e = 0.001111

Satellite in day light time

- Keep satellite centered
- Draw footprint, with a step of:

☐ Draw the track of satellite
Appendix
Megha-Tropiques / ScaRaB

Altitude = 865.5 km * Inclination = 19.98 ° * Half-swath = 48.9° * Max. Theta 58.9° [J] = 5 * Th. 0 min. = 7.1° [L] = 1

JUNE

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 °

OSur/O = 61 %
Overpasses: 176 pts
Overpasses w. Sun: 107 pts
6 consecutive overpasses

Evolution of cyclone Thane on December 29, 2011

<table>
<thead>
<tr>
<th>Time Range</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1105-1107</td>
<td>29.12 10H</td>
</tr>
<tr>
<td>1107-1108</td>
<td>29.12 11H50</td>
</tr>
<tr>
<td>1108-1109</td>
<td>29.12 13H40</td>
</tr>
<tr>
<td>1109-1110</td>
<td>29.12 15H30</td>
</tr>
<tr>
<td>1110-1111</td>
<td>29.12 17H20</td>
</tr>
<tr>
<td>1111-1112</td>
<td>29.12 19H05</td>
</tr>
</tbody>
</table>

Instrument SAPHIR
Megha-Tropiques

12° N

TABLEAU MENSUEL

[7] : Trace

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

CHAMP DE VUE : 85.9°

(1) DIRECTION P-S
  △ ASC  ▼ DES
  Sens trigonom. direct.
  - Angle zénithal (dans le plan perpendiculaire à la trace).
  - Azimut (dans le plan horizontal local) par rapport au Nord.

ORBITE a = 7243.615 km
Altitude = 865.5 km
Inclinaison = 19.98°
Décûlage équ. = 2822.0 km
Période = 101.93 min
Moyen mvt = 14.13 tours/j

BALAYAGE
Demi-phauche = 43.0°
Ang. Zénithal maximal = 50.7°
D. phauche sol = 852.8 km
Fr. recouvrement équ. = 1.628
Lat. max. atteinte = 27.7°

Ìξìων
MC ★ LMD
NORAD

Two-line Elements (TLE)

- $a$: semi-major axis
- $i$: inclination
- $e$: eccentricity
- $\Omega$, $\omega$, $M$: 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: $h = a - R$
  
  $R = \text{Earth equatorial radius}$
Comparison with the Sun-Synchronous satellites
Gan (Maldives)

**INITIALISATION**

ASCENDING NODE (AN): *Longitude AN = 0.0 ° * Time = 12h 00min LMT / AN

**MONTHLY TABLE**

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

FIELD OF VIEW: 97.8 °

(1) F-S DIRECTION
(2) ASC DES

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

**ORBIT**
- a = 7243.700 km
- Altitude = 865.8 km
- Inclination = 20.00 °
- Equatorial shift = 2892.0 km
- Period = 101.93 min
- Mean rate = 11.10 rev/day

**SCANNING**
- Half-swath = 48.9 °
- Maximal zenith angle = 58.9 °
- H-swath (ground) = 110.53 km
- Equatorial overlap = 2099
- Max. attained latt = 30.0 °
Aqua / CERES

10° N
MONTHLY TABLE

OVERPASSES (n = 69)
OF SATELLITE S [EGM96]
FOR POINT P
- Latitude: 10.0° N
- Longitude: 75.0° E
For P, UTC = LMT - 0h 00m

FIELD OF VIEW: 123.6°

P-S DIRECTION
ASC ➤ DES

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 = 7077.736 km
Altitude = 699.6 km
Incl. / Sun-s. = 98.21°
Equatorial shift = 2751.9 km
Period = 98.68 min
Mean rot. = 14.86 rev/day

SCANNING
Hori. swath = 61.8°
Max. horizontal zenith angle = 78.0°
Hori. swath (ground) = 18012 km
Equatorial overlap = 1.336
Max. attained lat. = 90.0°
Latit. overlap: 82.0° <- 90.0°

IEWOV
MC * LMD
Ouagadougou (BF)