HIRDLS

TC	NCA	062B

High Resolution Dynamics Limb Sounder

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Subject/Title: HIRDLS Science Modes and Scanning Commands Sequence Document

Contents:

- HIRDLS instrument operation approaches.
- HIRDLS Line-of-Sight (LOS) and scan mirror operations.
- HIRDLS viewing geometry simulation.
- HIRDLS science modes in more detail than given in the Science Requirements Document (SRD) and Instrument Requirements Document (IRD).
- Basic scanning operation sequences for each science mode.
- Viewing geometry and ground tracks of different science modes.
- Coverage plots for two orbits and one day.
- Mode changes in a typical orbit.

Note:

This is a revision to an earlier version TC-NCA-062A. Effect of sunshield operation on data collection is not considered at this time. The document should be regarded as a ”living” document; it is intended that it will continue to be refined over time as the HIRDLS program progresses. The document will be updated based on input from the HIRDLS team and the scientific community.

Key Words: Science Modes, Scanner Operations, Viewing Geometry, IPS

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1.0 Objectives and Scope of the Document

This document is intended to provide additional detail on proposed HIRDLS science observing modes and the sequences of scanner commands that may be necessary to implement them. The purpose of the document is to provide a context for establishing requirements for command and telemetry, requirements for in-flight software and associated tools, requirements for on-board processor hardware, and requirements for operations strategies.

Within this document, we attempt: (1) to describe HIRDLS science modes in more detail than given in the Science Requirements Document (SRD) and Instrument Requirements Document (IRD); (2) to outline how and when (e.g. under what circumstances) those science modes will be executed; (3) to define the basic scanning operations sequences for each science mode; (4) to define sequence scenarios in which those science modes might be carried out so that we might estimate a maximum number of mode changes within a specified time interval for use in processor sizing; (5) to present the viewing geometry and ground tracks of different science modes as an aid to HIRDLS scientists in conceptualizing operations strategies aimed at addressing particular science investigations.

2.0 Related Documentation

HIRDLS Science Requirements Document (SRD), SC-HIR-12B,
Latest Revision: 15 September 1995.

HIRDLS Instrument Requirements Document (IRD), SC-HIR-18K,
Latest Revision: 30 April, 1994.

HIRDLS Instrument Technical Specification (ITS), SP-HIR-13N

Command and Telemetry Handbook (C&TH) for HIRDLS (Preliminary), SP-HIR-103 Latest Revision: 12 Dec 1995.

SDP Toolkit Users Guide for the ECS Project, EOSDIS Core System Project Document 333-CD-003-002, Hughes Information Technology Corporation, Landover, Maryland.

Scan Mirror Angles and LOS Directions, TC-OXF-28B

3.0 HIRDLS Instrument Operation Approaches

HIRDLS is designed to be versatile and highly adaptable in its ability to scan the atmosphere both in the vertical and horizontal. In addition, other aspects of the instrument are intended to be reconfigurable on orbit to adapt operation to unforeseen events. This will be achieved through the Instrument Processor Subsystem (IPS) which will be programmable in a high level language. Control of the HIRDLS scan sequences and other instrument subsystems as well as interaction with the spacecraft data and navigation systems will be accomplished with routines written in this high level language. Tools will be developed to assist the HIRDLS science team in the development, maintenance and adaptation of these control procedures.

It is expected that a significant fraction of the duty cycle of the IPS will be devoted to control of the two-axis scanner which directs the instrument line-of-sight in elevation and azimuth to desired atmospheric and calibration targets, and the sun shield, which prevents the direct solar beam from entering the aperture of the instrument. This aspect of instrument control will be the focus of this discussion.

Control of the instrument scan could be accomplished in two ways. In the first approach, a detailed series of time tagged scan command sequences could be uploaded from the ground in the form of microprocessor loads (Microloads). In the most basic implementation, this would require accurate orbit predictions to be available to operations teams on the ground sufficiently far in advance to allow the Microloads to be generated and routed through instrument and spacecraft control centers. Depending upon the complexity of the scan sequences and the number of discrete commands required to represent them, frequent uploads or considerable spacecraft or IPS memory could be required to carry out the desired science observations.

Alternatively, standard command sequences could be generated within the instrument in real-time by prestored routines in the IPS. Characteristics of the scans such as vertical extent, horizontal extent or rate could be described parametrically by arguments to the routine. Some of these parameters may be provided through uploads from the ground. Other parameters such as spacecraft location and time may be acquired directly from the spacecraft computer. Such standard scan sequences which are generated algorithmically will be referred to here as Modes. Generation of these scan sequences will likely require a relatively low volume of information to be uplinked but could place significant requirements on the computational capacity of the on-board processor. Of course, new scan sequence routines could be uploaded and placed in the IPS should the need arise.

Trade-offs should be carried out to assess which of these approaches (or some combination) best satisfy HIRDLS science, operations, budget and reliability requirements. The outcome of such studies can then appropriately guide the selection of hardware and flight software development.

4.0 HIRDLS Line-of-Sight (LOS) and Scan Mirror Operations

In order to specify scanner elevation angle, azimuth angle, and scan mirror scan rate, the relationships between scanner angles and LOS angles need to be derived. In the initial analysis presented here, a spherical Earth with an average radius of 6367 km and a constant spacecraft altitude of 705 km were assumed. In more exact calculations, the oblateness of Earth and spacecraft orbit need to be considered. Following the definition in TC-OXF-28B, the scan mirror normal vector is defined as,

$$\vec{M} = \begin{bmatrix} \cos(\phi_m)\cos(\varepsilon_m) \\ \sin(\phi_m)\cos(\varepsilon_m) \\ -\sin(\varepsilon_m) \end{bmatrix} \tag{4.1}$$

where ϕ_m is the scan mirror azimuth angle, ε_m is the scan mirror elevation angle. The ray vector incident on the scan mirror from the telescope is defined as,

$$\vec{T} = \begin{bmatrix} \cos(\phi_{FOV})\cos(\varepsilon_{POA} + \varepsilon_{FOV}) \\ -\sin(\phi_{FOV})\cos(\varepsilon_{POA} + \varepsilon_{FOV}) \\ -\sin(\varepsilon_{POA} + \varepsilon_{FOV}) \end{bmatrix} \tag{4.2}$$

where ϕ_{FOV} is the azimuth angle of a certain detector within the instrument field-of-view, ε_{FOV} is the elevation angle within the instrument field-of-view, and ε_{POA} is the instrument boresight angle. The Line-of-Sight (LOS) vector is defined as,

$$\vec{L} = \begin{bmatrix} -\cos(\phi_{LOS})\cos(\varepsilon_{LOS}) \\ -\sin(\phi_{LOS})\cos(\varepsilon_{LOS}) \\ \sin(\varepsilon_{LOS}) \end{bmatrix} \tag{4.3}$$

where ϕ_{LOS} is the LOS azimuth angle, and ε_{LOS} is the LOS elevation angle. It can be shown easily that,

$$\vec{L} = \vec{T} - 2(\vec{T} \bullet \vec{M})\vec{M} \tag{4.4}$$

If we only consider the Instantaneous Line-of-Sight of the boresight (ILOS), then we can set $\varepsilon_{FOV} = \phi_{FOV}$=0.0. Substitute equations (4.1), (4.2), and (4.3) in equation (4.4), we get,

$$\vec{L}_{ILOS} = \begin{bmatrix} -\cos(\phi_{ILOS})\cos(\varepsilon_{ILOS}) \\ -\sin(\phi_{ILOS})\cos(\varepsilon_{ILOS}) \\ \sin(\varepsilon_{ILOS}) \end{bmatrix}$$

$$= \begin{bmatrix} \cos(\varepsilon_{POA}) - 2\cos(\varepsilon_{POA})\cos^2(\phi_m)\cos^2(\varepsilon_m) + \sin(\varepsilon_{POA})\cos(\phi_m)\sin(2\varepsilon_m) \\ -\cos(\varepsilon_{POA})\sin(2\phi_m)\cos^2(\varepsilon_m) \quad + \sin(\varepsilon_{POA})\cos(\phi_m)\sin(2\varepsilon_m) \\ \sin(\varepsilon_{POA}) + \cos(\varepsilon_{POA})\cos(\phi_m)\sin(2\varepsilon_m) \quad - 2\sin(\varepsilon_{POA})\sin^2(\varepsilon_m) \end{bmatrix} \tag{4.5}$$

From (4.5), we can get the following,

$$\tan(\phi_m) = \frac{\sin(\phi_{ILOS})\cos(\varepsilon_{ILOS})}{\cos(\varepsilon_{POA}) + \cos(\phi_{ILOS})\cos(\varepsilon_{ILOS)}} \tag{4.6}$$

$$\tan(\varepsilon_m) = \frac{\sin(\varepsilon_{ILOS}) - \sin(\varepsilon_{POA})}{\cos(\varepsilon_{POA})\cos(\phi_m) + \sqrt{\cos^2(\varepsilon_{ILOS}) - \cos^2(\varepsilon_{POA})\sin^2(\phi_m)}}$$

$$= \frac{\cos(\varepsilon_{POA})\cos(\phi_m) - \sqrt{\cos^2(\varepsilon_{ILOS}) - \cos^2(\varepsilon_{POA})\sin^2(\phi_m)}}{\sin(\varepsilon_{ILOS}) + \sin(\varepsilon_{POA})} \tag{4.7}$$

$$\sin(\phi_{ILOS}) = \frac{\cos(\varepsilon_{POA})\cos^2(\varepsilon_m)\sin(2\phi_m) - \sin(\varepsilon_{POA})\sin(2\varepsilon_m)\sin(\phi_m)}{\cos(\varepsilon_{ILOS})} \tag{4.8}$$

$$\sin(\varepsilon_{ILOS}) = \sin(\varepsilon_{POA}) + \cos(\varepsilon_{POA})\sin(2\varepsilon_m)\cos(\phi_m) - 2\sin(\varepsilon_{POA})\sin^2(\varepsilon_m) \tag{4.9}$$

With a spherical Earth and constant orbit altitude approximations, the ILOS elevation angle can be related to the tangent height by,

$$R_E + H_t = R_{S/C}\cos(\varepsilon_{ILOS}) \tag{4.10}$$

where R_E is the average Earth radius, $R_{S/C}$ is the distance of the spacecraft from the center of the Earth, H_t is the tangent height, and ε_{ILOS} is the ILOS elevation angle. The ILOS elevation angle

range can be calculated given the tangent height range of each vertical scan. At H_t = 130.0, ε_{ILOS} = 23.264^o; and at H_t =-30 km, ε_{ILOS} = 26.354^o.

As pointed out before, in reality both R_E and $R_{S/C}$ will change along orbit, and R_E is also a function of sub-tangent point position on the Earth surface. Therefore, several iterations (possibly one or two) will be needed to determine ε_{ILOS} for the desired H_t and vice versa. The equations and algorithm for the calculation of tangent heights, LOS directions, scan mirror angles, and scan rates need to be implemented in both high level instrument control language (such as SAIL) and hardware for rapid on-board calculations considering the fact that those calculations might need to be conducted every vertical scan (~ 10 s).

5.0 HIRDLS Viewing Geometry Simulation

The theoretical basis and procedures for the calculation of HIRDLS viewing geometry including the tangent point height, tangent point longitude and latitude in the Earth-Centered Rotating (ECR) coordinate are presented in this section. Those tools (programs) could be a part of the HIRDLS flight operation planning aids. The viewing geometry and tangent point tracks for the HIRDLS Global Mode, Medium Resolution Mode, and High Resolution Mode are calculated as an example.

5.1 Definition of Coordinate Systems

Coordinates used in the calculation of spacecraft locations and HIRDLS viewing geometry are described in this section.

5.1.1 Earth-Centered Inertial (ECI) Coordinate System

The +Z axis of the ECI is pointed from the center of the Earth to the North Pole, the +X axis is from the center of the Earth to the vernal equinox, and the +Y axis completes the right-hand coordinate system. ECI does not rotate with the Earth.

5.1.2 Earth-Centered Rotating (ECR) Coordinate System

The +Z axis of the ECR is pointed from the center of the Earth to the North pole, the +X axis is from the center of the Earth to the Greenwich meridian, and the +Y axis completes the right-hand coordinate system. ECR rotates with the Earth.

5.1.3 Spacecraft Reference Coordinate Frame (SRCF) (ITS section 3.1.3.1)

The Spacecraft Reference Coordinate Frame is defined, in accordance with GIRD Section 9, as a right-handed rectangular coordinate system with the following axis definitions: +Z is toward the Earth, along a line connecting the S/C center of mass to the Earth center of mass; the Y-axis is normal to the plane of the orbit with +Y on the anti-sun side; the X-axis completes the coordinate system, with +X in the general direction of the spacecraft velocity vector. The X, Y, Z axes correspond approximately to the Roll, Pitch, and Yaw axes, respectively, of the S/C. This definition is for the original CHEM-1 platform with afternoon equator crossing time. If the platform and equator crossing time changes, such as from afternoon to morning equator crossing, the above SRCF definition needs to be changed accordingly.

5.1.4 Instrument Reference Coordinate Frame (IRCF) (ITS section 3.1.3.2)

The IRCF is a right-handed rectangular coordinate system having axes nominally parallel to those of the SRCF as defined in Section 3.1.3.1, but fixed with respect to the Instrument Baseplate. The origin of this coordinate system is at one corner of the Baseplate as shown in ITS Figure 3.1-1.

5.1.5 Telescope Reference Coordinate Frame (TRCF) (ITS 3.1.3.3)

The TRCF is a right-handed rectangular coordinate system having axes nominally parallel to those of the SRCF as defined in Section 3.1.3.1, but fixed with respect to the Optical Bench.

5.2 Generation of CHEM-1 Ephemeris Data

In order to calculate the position of the CHEM-1 spacecraft in the Earth-fixed coordinate system (ECR), the positions of the spacecraft with respect to the inertial coordinate system (ECI) provided by the spacecraft ephemeris data are needed. One possible approach of generating CHEM-1 ephemeris data is to use the AM-1/PM-1 tool kit. The nominal orbit altitude of 705 km and inclination of 98.2^o of CHEM-1 is the same as those PM-1, the difference is the equator crossing time. If a convenient way of correcting for the different crossing time can be found, then the ephemeris data for CHEM-1 can be generated with the current tool kit. In the viewing geometry calculations presented here, PM-1 is used as a surrogate of CHEM-1.

5.3 Transformation of Spacecraft position in Inertial Coordinate System to Earth Fixed Coordinate System

The matrix for the transformation from inertial coordinate system (ECI) to Earth fixed coordinate system (ECR) is

$$\begin{bmatrix} X_F \\ Y_F \\ Z_F \end{bmatrix} = \begin{bmatrix} \cos v(t) & \sin v(t) & 0 \\ -\sin v(t) & \cos v(t) & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} X_I \\ Y_I \\ Z_I \end{bmatrix} \tag{5.3.1}$$

where ν(t) is the time dependent rotation angle of the Earth fixed frame with respect to the inertial frame and is given by

$$v(t) = 99.6909833^o + 36000.7689^o t + 0.00038708^o t^2 + 360.9856463^o \Delta d \tag{5.3.2}$$

where t is Julian centuries since 1900 , and Δd is fractional days between the measurement time and the midnight universal time.

$$t = (JD - 2415020)/36525 \tag{5.3.3}$$

5.4 Transformation of HIRDLS Telescope (or Detector) Pointing Vector to Earth-Fixed Coordinate System

HIRDLS ILOS vector in the TRCF coordinate is given by

$$\begin{aligned} X_T &= -\cos\beta\cos\alpha \\ Y_T &= -\cos\beta\sin\alpha \\ Z_T &= \sin\beta \end{aligned} \tag{5.3.4}$$

Where α is azimuth angle in TRCF, and β is elevation angle in TRCF. β will be given by the summation of boresight angle of 25.3^{o} and scanner elevation angle. In matrix form, the pointing vector in TRCF is given by

$$\begin{bmatrix} X_T \\ Y_T \\ Z_T \end{bmatrix} = \begin{bmatrix} \cos\beta\cos\alpha & -\sin\alpha & \sin\beta\cos\alpha \\ \cos\beta\sin\alpha & \cos\alpha & \sin\beta\sin\alpha \\ -\sin\beta & 0 & \cos\beta \end{bmatrix} \begin{bmatrix} -1 \\ 0 \\ 0 \end{bmatrix} \tag{5.3.5}$$

The roll, pitch, and yaw angles of the instrument optical bench measured by the HIRDLS gyro will generally not be zero, which means that the TRCF is rotated with respect to the local horizon coordinate. The transformation from TRCF to the local horizon coordinate (X_H, Y_H, Z_H) is given by

$$\begin{bmatrix} X_H \\ Y_H \\ Z_H \end{bmatrix} = \begin{bmatrix} \cos q\cos r - \sin p\sin q\sin r & -\sin r\cos p & \sin q\cos r + \sin p\sin r\cos q \\ \sin r\cos q + \sin p\sin q\cos r & \cos p\cos r & \sin q\sin r - \sin p\cos q\cos r \\ -\sin q\cos p & \sin p & \cos p\cos q \end{bmatrix} \begin{bmatrix} X_T \\ Y_T \\ Z_T \end{bmatrix} \tag{5.3.6}$$

where p, q, and r represent the roll, pitch, and yaw angles of the instrument bench (TRCF) about the X_H, Y_H, and Z_H axes of the local horizon coordinate respectively. In our preliminary LOS calculation and simulation, p, q, and r are assumed to be zero, and the TRCF is parallel to the local horizon coordinate.

The local horizon coordinate system is rotated about nadir with respect to the local geodetic coordinate system due to the inclination of the orbit. The rotation angle η, called the heading angle, is the angle between geodetic north and the projection of the spacecraft velocity vector onto the local horizon coordinate system. The LOS pointing vector is both rotated by the heading angle and transformed to the Earth fixed coordinate system (ECR) by

$$\begin{bmatrix} X_F \\ Y_F \\ Z_F \end{bmatrix} = \begin{bmatrix} -\cos\eta\cos\Lambda\sin\Phi_G + \sin\eta\sin\Lambda & -\sin\eta\cos\Lambda\sin\Phi_G - \cos\eta\sin\Lambda & -\cos\Lambda\cos\Phi_G \\ -\cos\eta\sin\Lambda\sin\Phi_G - \sin\eta\cos\Lambda & -\sin\eta\sin\Lambda\sin\Phi_G + \cos\eta\cos\Lambda & -\sin\Lambda\cos\Phi_G \\ \cos\eta\cos\Phi_G & \sin\eta\cos\Phi_G & -\sin\Phi_G \end{bmatrix} \begin{bmatrix} X_T \\ Y_T \\ Z_T \end{bmatrix} \tag{5.3.7}$$

where Λ and Φ_G are the Earth fixed longitude and geodetic latitude of the spacecraft. The Earth fixed longitude and geocentric latitude can be derived from the position of the spacecraft. The geodetic latitude is determined from the geocentric latitude Φ_C by

$$\Phi_G = \tan^{-1}(\tan\Phi_C R_e^2 / R_p^2) \tag{5.3.8}$$

where R_e and R_p are the equatorial and polar radii respectively.

5.5 Calculation of Tangent Height and Sub-Tangent Point Latitude and Longitude

Once the spacecraft position and instrument pointing vectors are known in the Earth fixed coordinate system, the LOS tangent height and the sub-tangent point latitude and longitude can be obtained by finding the tangential point between a line passing through the spacecraft position and parallel to the instrument pointing vector and an ellipsoid described by the following equation,

$$\frac{X^2}{(R_e+h)^2}+\frac{Y^2}{(R_e+h)^2}+\frac{Z^2}{(R_p+h)^2}=1 \tag{5.3.9}$$

Let the spacecraft position in the Earth fixed coordinate be X_0, Y_0, Z_0 , and is given by

$$\vec{P} = X_0\vec{i} + Y_0\vec{j} + Z_0\vec{k} \tag{5.3.10}$$

The instrument pointing unit vector is given by

$$\vec{V}_{LOS} = X_{LOS}\vec{i} + Y_{LOS}\vec{j} + Z_{LOS}\vec{k} \;\; and \;\; \left|\vec{V}_{LOS}\right| = 1 \tag{5.3.11}$$

Then the tangent height and the location of the tangent point (latitude, longitude) can be determined by solving the following equations

$$\begin{aligned} &\frac{X^2}{(R_e+h)^2}+\frac{Y^2}{(R_e+h)^2}+\frac{Z^2}{(R_p+h)^2}=1 \\ &\frac{X-X_0}{X_{LOS}} = \frac{Y-Y_0}{Y_{LOS}} = \frac{Z-Z_0}{Z_{LOS}} = g \end{aligned} \tag{5.3.12}$$

These two equation can be reduced to a quadratic equation in terms of g as

$$Ag^2 + Bg + C = 0 \tag{5.3.13}$$

Where A,B, and C are given by

$$\begin{aligned} A &= (R_p+h)^2(X_{LOS}^2+Y_{LOS}^2)+(R_e+h)^2 Z_{LOS}^2 \\ B &= 2[(R_p+h)^2(X_{LOS}X_0+Y_{LOS}Y_0)+(R_e+h)^2 Z_{LOS}Z_0] \\ C &= (R_p+h)^2(X_0^2+Y_0^2)+(R_e+h)^2 Z_0^2-(R_p+h)^2(R_e+h)^2 \end{aligned} \tag{5.3.14}$$

The distance from spacecraft to the intersection point is given by

$$g = \frac{-B \pm \sqrt{B^2-4AC}}{2A} \;\; and \;\; \vec{g} = g(X_{LOS}\vec{i} + Y_{LOS}\vec{j} + Z_{LOS}\vec{k}) \tag{5.3.15}$$

The vector, R, from center of the Earth to the intersection point is given by

$$\vec{R} = \vec{P} + \vec{g} \tag{5.3.16}$$

and the longitude and latitude of the intersection point is given by

$$\begin{aligned} \Lambda &= \tan^{-1}(R_y / R_x) \\ \Phi &= \sin^{-1}(R_z / |\vec{R}|) \end{aligned} \tag{5.3.17}$$

If one needs to find the tangent point, then the following equation needs to be solved for h,

$$B^2 - 4AC = 0 \tag{5.3.18}$$

In the preliminary simulation presented in the following sections, the approximation $R_{equator}$= R_{pole} =R is used to simplify the solution of the quadratic equation (5.3.18). That is the Earth is assumed to be a sphere rather than an ellipsoid. The error caused by this approximation is expected to be small. The solutions will be refined later on by using the ellipsoid model when the CHEM-1 satellite orbital elements and ephemeris data become available. With the spherical Earth approximation, equation (5.3.15) can be simplified as,

$$g = ABS(X_{LOS}X_0 + Y_{LOS}Y_0 + Z_{LOS}Z_0) \tag{5.3.19}$$

and the tangent point coordinates in ECR are given by,

$$\begin{aligned} X_t &= X_0 + g \times X_{LOS} \\ Y_t &= Y_0 + g \times Y_{LOS} \\ Z_t &= Z_0 + g \times Z_{LOS} \end{aligned} \tag{5.3.20}$$

the tangent point distance from the center of the Earth is given by,

$$R_t = \sqrt{X_t^2 + Y_t^2 + Z_t^2} \tag{5.3.21}$$

the tangent point latitude, longitude, and tangent height are given by,

$$\begin{aligned} T_{LAT} &= ASIN(Z_t/R_t)*180.0/\pi \quad \text{(degree)} \\ T_{LONG} &= ATAN2(Y_t, X_t)*180.0/\pi \quad \text{(degree)} \\ H_t &= SQRT(B1-B2**2)-R \end{aligned} \tag{5.3.22}$$

where R = radius of the Earth = 6367 (km),
$B1 = X_0^2+Y_0^2+Z_0^2$,
$B2 = X_0*X_{LOS}+Y_o*Y_{LOS}+Z_0*Z_{LOS}$.

In section 6.0 the HIRDLS coverage and tangent point track simulation for the Alternative Global Mode, Medium Resolution Mode, and High Resolution Mode are presented as examples. The simulations are carried out with fixed scan mirror azimuth step between two vertical scans in

a swath to simplify calculations, therefore the resolutions are more like constant spacing rather than constant angles on the latitude and longitude circles. More elaborate simulations for constant angle resolutions will be presented in the next version of the document. For constant angle resolutions, the scan mirror azimuth angle need to be calculated every swath, and possibly every vertical scan. The viewing geometry and tangent point tracks of other HIRDLS science modes can also be calculated in the same way.

6.0 HIRDLS Science Modes and Scan Characteristics

The concept of standard scan sequences or "Modes" was introduced in section 3.0. HIRDLS is being designed to have the flexibility to acquire observations specifically tailored to a wide range of scientific problems. Unfortunately, the scan sequences required to address a specific problem may be unsuitable for other types of investigations. Certain atmospheric problems can only be investigated in particular seasons or at certain geographic locations and may require special scan patterns. It will be the responsibility of the HIRDLS Science Team to plan the operation of the instrument to obtain the optimum scientific return given possible conflicting requirements. To accomplish this it may be necessary at times to change modes several times within a day or even several times within orbits. In the following sections, various modes which have been identified for particular scientific applications will be discussed. In subsequent sections, the characteristics of these scans in terms of the two-axis scanner operation are described. A possible operation sequence involving several mode changes within one orbit is presented as an example.

6.1 Global Mode (5° x 4°)

Many of the HIRDLS scientific objectives require data which have homogeneous characteristics over the life of the mission. This implies considerable uniformity in the way the data are originally acquired both spatially and temporally. Most atmospheric models which incorporate such data utilize equal angle grid projections for computational efficiency. Equal angle spacing also results in closer physical spacing of profiles in the longitudinal direction in polar regions. This can be important in resolving phenomena with large horizontal gradients particular in the winter pole. The Global Mode will be the default for normal scientific data collection. Currently, limb scans in Global Mode are to be conducted with a nominal spacing of ~5° longitude and 4° latitude between adjacent points including points from succeeding and preceding orbits. Note that this does not imply that data will be acquired at fixed latitude and longitude points relative to the Earth each day. Interpolation to Earth fixed grids will be done as part of the Level-3 processing of HIRDLS Science Data Products.

The scan characteristics of the global mode in terms of the two-axis scanner operation is described below. Figure 6.1.1 is a schematic diagram of the global mode scan sequence. In order to achieve the 5° longitude and 4° latitude resolution, the scan mirror azimuth angles of each vertical scan need to be calculated for every swath. Global mode viewing geometry and tangent tracks simulation will be included in the next version of this document.

Conditions for the mode:	default scan mode, conducted at least every 12 hours (TBV).
Spatial resolution:	5° x 4°
ILOS elevation scan range:	23.264 to 26.354 ^{o} (130 km to -30 km)*
ILOS Azimuth scan range:	TBD. Calculated every swath.
Scanner scan rate:	TBD. 65.5 sec/swath, 9.5 sec/scan

* Note: the angles are calculated based on a spherical Earth and constant orbit height approximations. They will change slightly if the oblateness of the Earth and orbit are considered. In the next revision of the document, the oblateness of the Earth and orbit will be considered. This comment is also applicable to other HIRDLS modes to be discussed in the following sections.

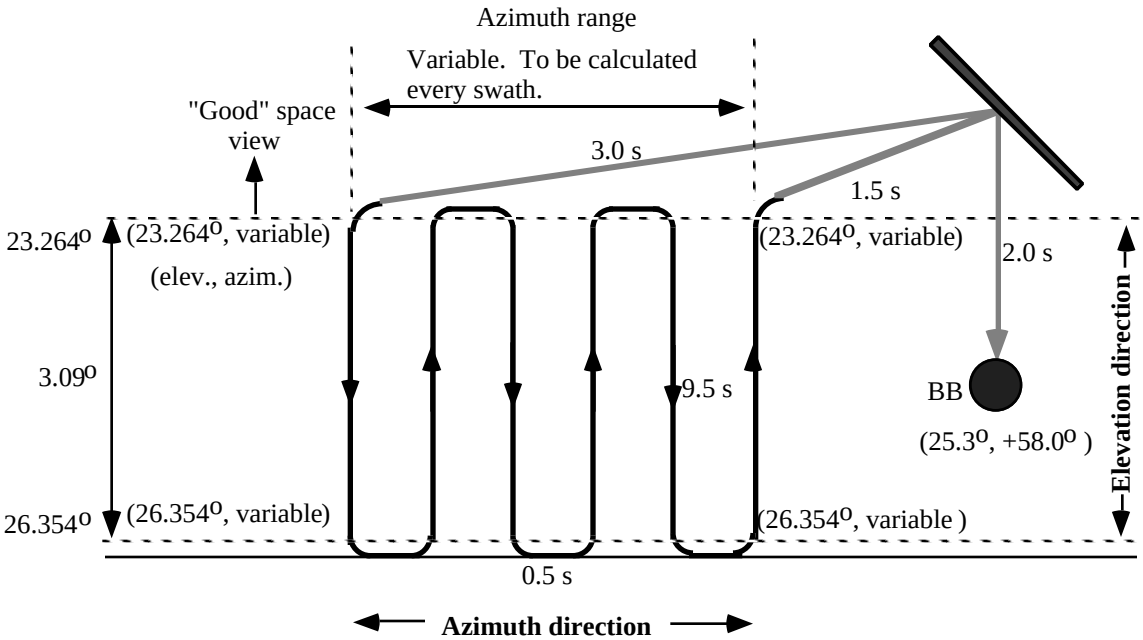


Fig. 6.1.1 Global mode scan sequence diagram.

6.2. Alternative Global Mode (500 km x400 km)

Certain science investigations emphasize changes in the atmosphere on time scales of a few hours. By acquiring data with fixed distances between profiles in the horizontal, some of the same geographical regions can be resampled on successive orbits at the higher latitudes. At the same time, sampling at low latitudes fits the requirements for uniformity described above. This mode observes the atmosphere with a nominal spacing of ~500 km between profiles in the longitudinal direction and ~400 km in the latitudinal direction.

The scan characteristics of the alternative global mode in terms of the two-axis scanner operation is described below. Figure 6.2.1 is a schematic diagram of the alternative global mode scan sequence. Figure 6.2.2 shows HIRDLS boresight (elevation angle of 25.3 degree) tangent point latitude and longitude in the alternative global mode for two orbits, about 200 minutes. The ILOS azimuth scan range is from -40.0^{o} to 20.0^{o}, each vertical scan takes 9.5 seconds, azimuthal slew from one vertical scan to the next within one swath takes 0.5 second, and each swath takes 65.5 seconds. Within one orbit, the spacing between two adjacent scans is approximately 12.0^{o} in terms of ILOS azimuth angle, and 6.0^{o} in terms of scan mirror azimuth angle. The azimuth scan range and steps between two adjacent vertical scans are used as an example, other values can be used if desired. Figure 6.2.3 shows the boresight tangent point latitudes and longitudes for one day, the filled circles are for ascending orbits, and the open circles are for descending orbits. Fig. 6.2.4 shows the tangent point latitudinal and longitudinal differences of adjacent scans. It can be seen that the nominal 500 km x 400 km resolution of the alternative global mode is achieved. Due to the equator overlap requirement for gyro calibration, large azimuth angles and slew rates are needed. Those issues should be re-examined carefully to assess the consequences. Details of scan mirror and ILOS angles are listed in table 6.2.1.

Conditions for the mode:	Coverage of higher latitudes every orbit. Conducted on demand.
Spatial resolution:	500 km x 400 km (Longitude x Latitude)
ILOS elevation scan range:	23.264 to 26.354 ^{o} (130 km to -30 km)
ILOS Azimuth scan range:	-40.0 ^{o} to 20.0^{o}
Scanner scan rate:	0.163^{o}/s - 0.173^{o}/s , 65.5 sec/swath, 9.5 sec/scan
Maximum azimuth slew rate:	32.96^{o}/s (-40.879^{o} to 58.0^{o} in 3.0 s)
Maximum elevation slew rate:	1.357^{o}/s (25.3^{o} to 23.264^{o} in 1.5 s)

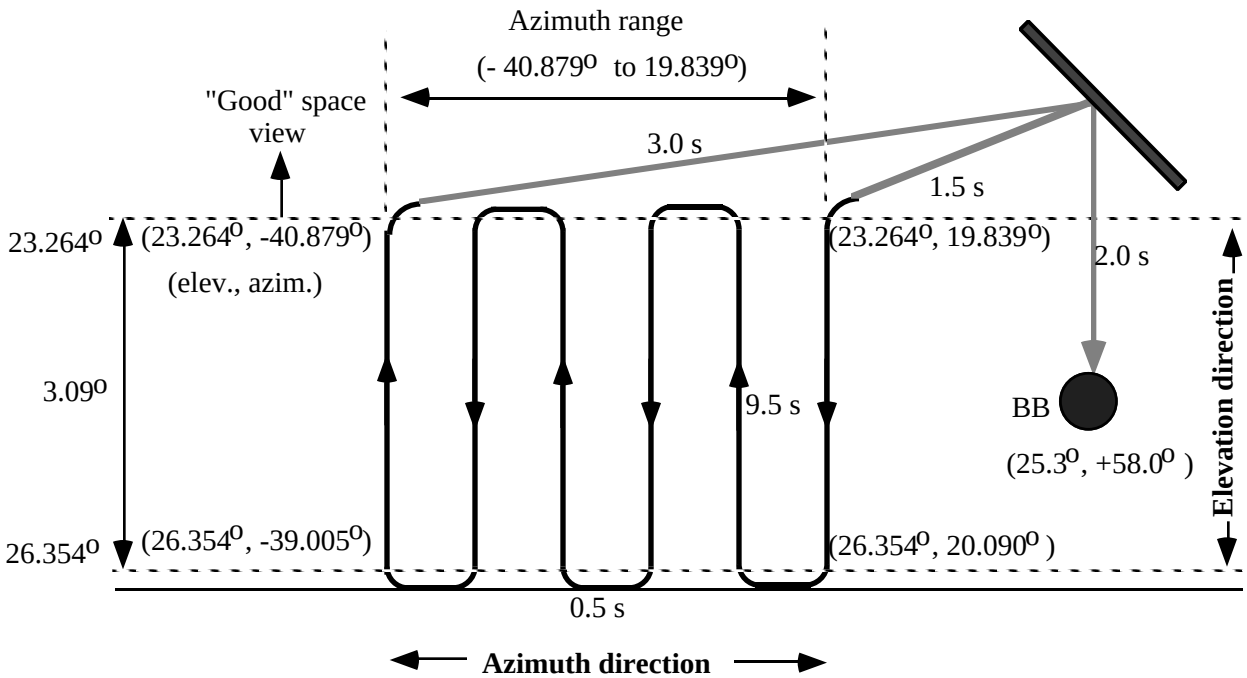
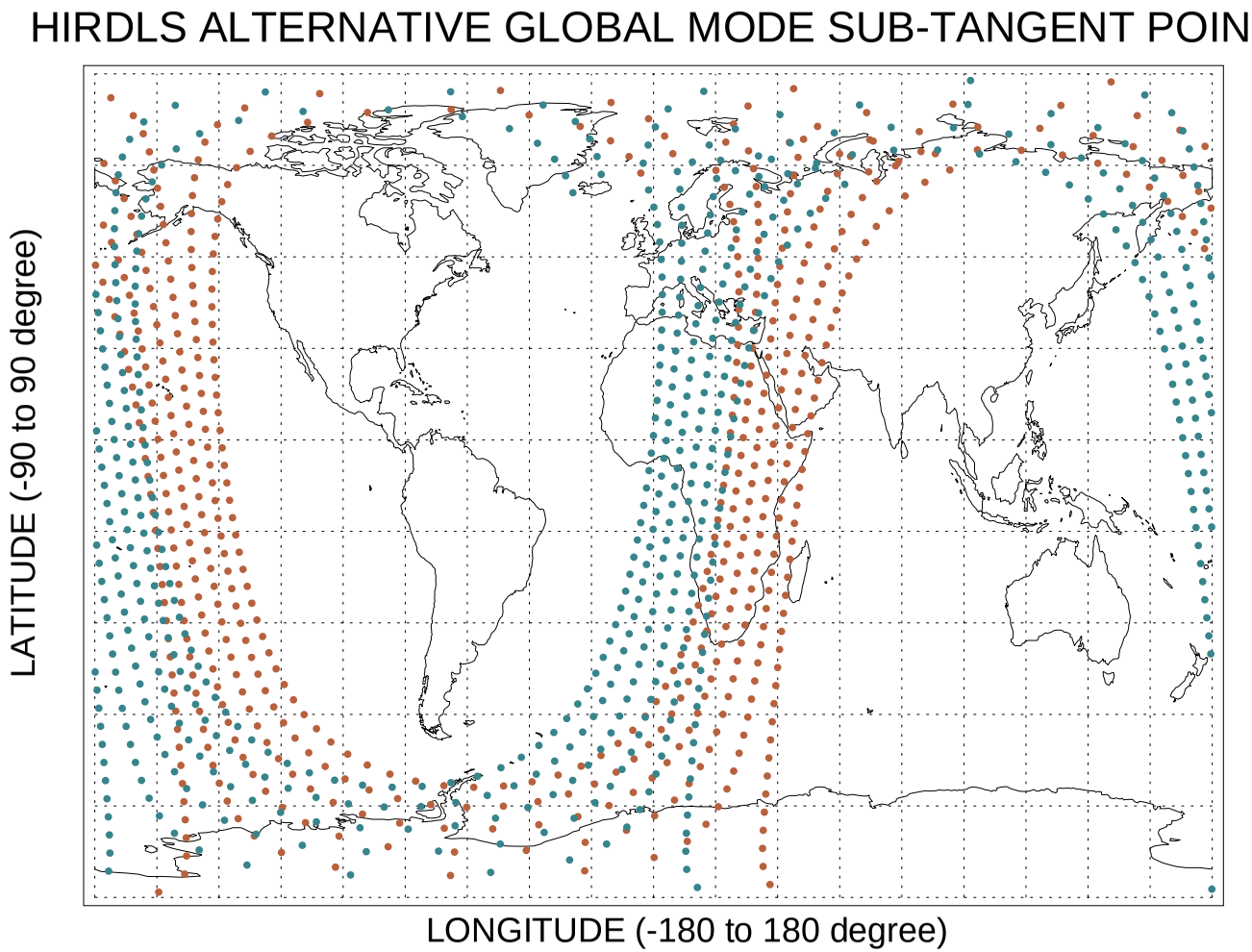


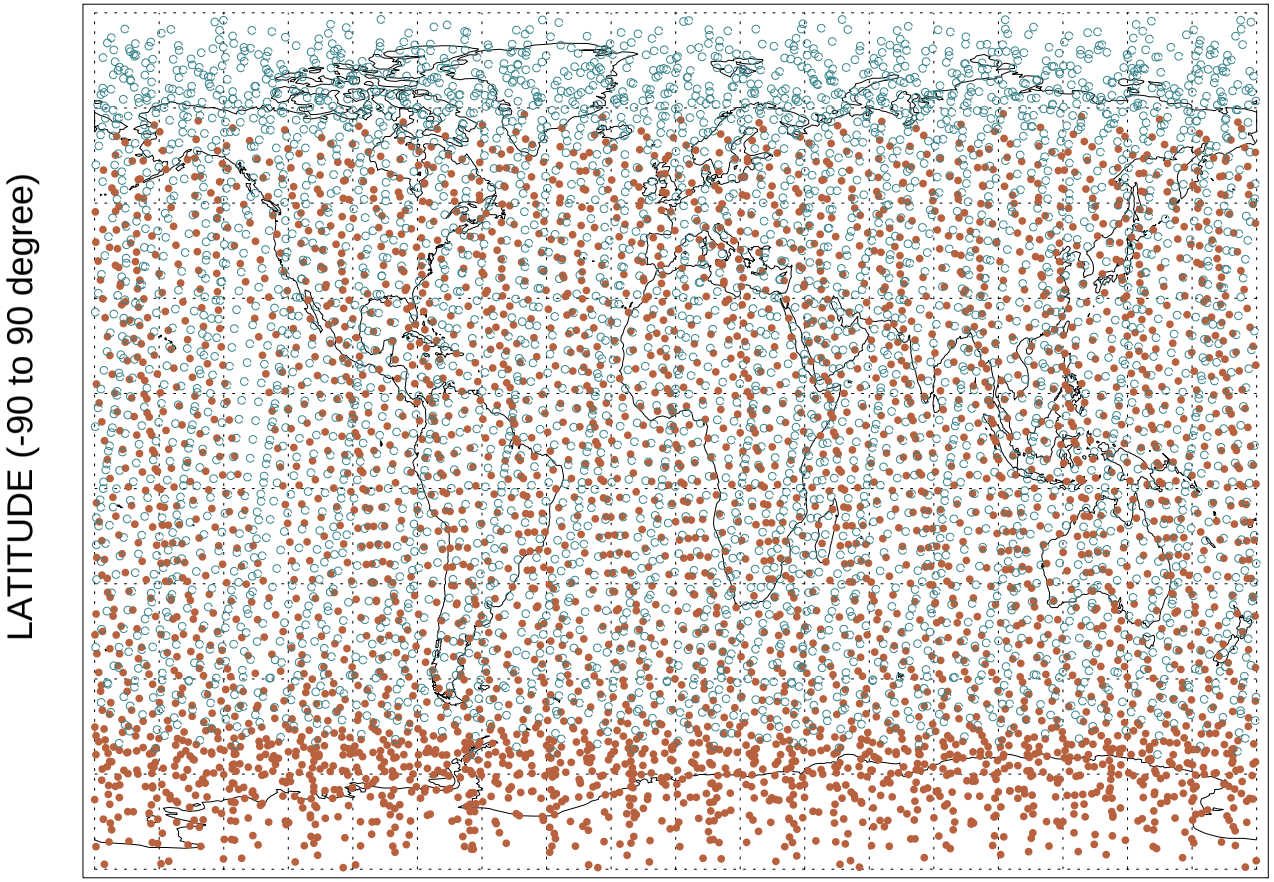
Fig. 6.2.1 Alternative global mode scan sequence diagram.



EOS/PM orbit from SDP Toolkit
Starting time: 2003-01-01T00:00:00.000000
Swath time: 66 sec; Single vertical scan time: 9.5 sec
Coverage for two orbits (~12,000 s). ILOS azimuth range: -40.9 to 20.1 degree.

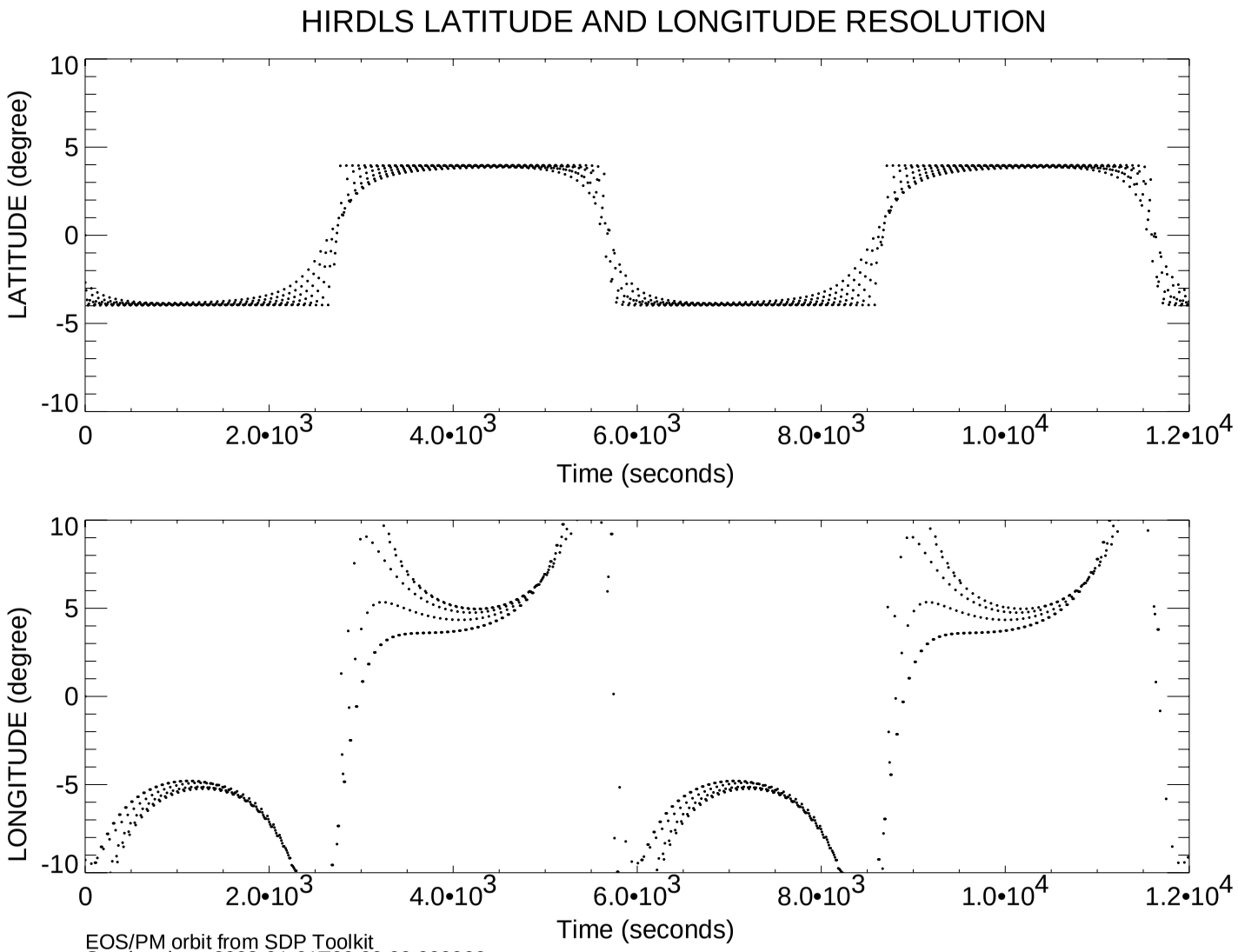
Fig. 6.2.2 HIRDLS boresight tangent point latitudes and longitudes in the Alternative Global Mode for two orbits

HIRDLS ALTERNATIVE GLOBAL MODE SUB-TANGENT POINT



EOS/PM orbit from SDP Toolkit, coverage for one day(86,400 s)
Starting time: 2003-01-01T00:00:00.000000
Swath time: 66 sec; Single vertical scan time: 9.5 sec
ILOS azimuth range: -40.9 to 20.1 degree
Solid circle: ascending orbits; Open circle: descending orbits tangent points.

Fig. 6.2.3 HIRDLS boresight tangent point latitudes and longitudes in the Alternative Global Mode for one day



EOS/PM orbit from SDP Toolkit
Starting time: 2003-01-01T00:00:00.000000
Swath time: 65.5 sec; Single vertical scan time: 9.5 sec
Global Mode coverage for one day (86,400 s). ILOS azimuth range: -40.9 to 20.1 degree.

Fig. 6.2.4 HIRDLS latitude and longitude difference between two adjacent scans in the Alternative Global Mode.

Table 6.2.1 Detailed scan mirror and ILOS angles for alternative global mode.

Assumptions:

1. Spherical Earth and constant S/C altitude approximation: R_E = 6367 km
   $R_{S/C}$ = 7072 km
2. ILOS lower tangent height: H_1 = -30 km
   ILOS upper tangent height: H_2 = 130 km
3. Single vertical scan: 9.5 s, 1st scan from top to bottom (H_2 to H_1)

Time (s)		**ILOS Elevation (degree)**		**ILOS Azimuth (degree)**		**Scan Mirror Elevation (degree)**		**Scan Mirror Azimuth (degree)**		**Mirror Scan Rate (deg/s)**
Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final	
Single elevation scan at zero azimuth angle										
0.0	9.5	23.264	26.354	0.00	0.00	-1.018	0.527	0.00	0.00	0.163
6 elevation scan in a swath										
0.0	9.5	23.264	26.354	19.839	20.090	-1.033	0.535	10.0	10.0	0.165
10.0	19.5	26.354	23.264	7.837	8.138	0.528	-1.020	4.0	4.0	-0.163
20.0	29.5	23.264	26.354	-3.968	-4.018	-1.019	0.527	-2.0	-2.0	0.163
30.0	39.5	26.354	23.264	-15.666	-16.284	0.532	-1.028	-8.0	-8.0	-0.164
40.0	49.5	23.264	26.354	-27.773	-28.128	-1.049	0.543	-14.0	-14.0	0.168
50.0	59.5	26.354	23.264	-39.005	-40.879	0.561	-1.082	-20.0	-20.0	-0.173

Note: The LOS scan rates are approximately 2 times those of the scan mirror scan rates.

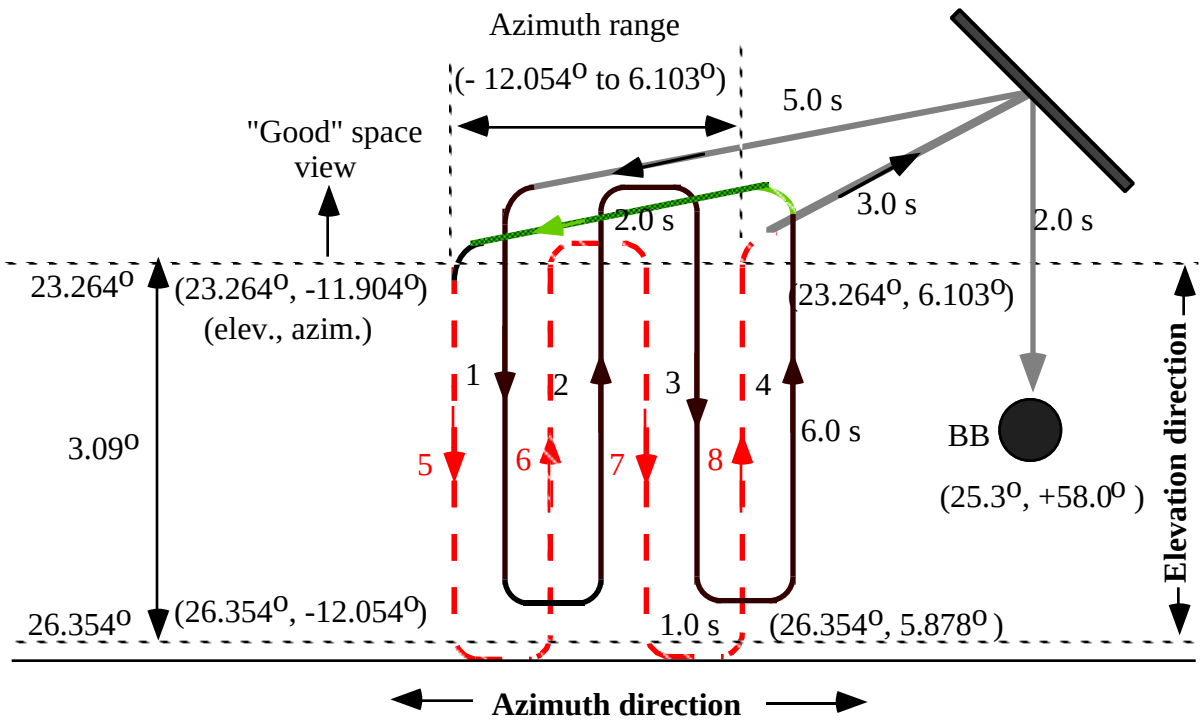
6.3 Medium Resolution Mode ($2.5^o x 2^o$)

Several atmospheric phenomena of concern to HIRDLS investigators exhibit significant variability on scales smaller than can be resolved with the "Global" modes. Among these are the polar vortex boundaries, certain photochemically active trace gases around the day/night terminator, and dynamical parameters over part of the gravity wave spectrum. The medium resolution mode acquires profiles spaced ~2.5^o apart in the longitudinal direction and ~2° in the latitudinal direction. This mode will result in significant gaps between successive orbits and hence its use will need to be planned in the context of an overall observing strategy to minimize global data inhomogenity.

In the simulation of the medium resolution mode, it is assumed that the blackbody (BB) view is conducted every two swaths, rather than every swath as in the global mode and alternative global mode. The advantage of this approach is that it will lead to some time saving, and thereby reduce the vertical scan rate requirement. The disadvantage of this approach is that it results in slightly nonuniform latitude resolution for different swaths. However, the difference is relatively small, about 0.5^o or less, and it should have little impact on the use of the data, especially in the context of data assimilation.

The scan characteristics of the medium resolution mode in terms of the two-axis scanner operation are described below. Figure 6.3.1 is a schematic diagram of the global mode scan sequence. The ILOS azimuth scan range is from -12.0^o to 6.0^o, each vertical scan takes 5.5 seconds, azimuthal slew from one vertical scan to the next within one swath takes 0.5 second, and the time for two swaths between BB view is 66 seconds. Within one swath, the spacing between two adjacent scans is 6.0^o in terms of ILOS azimuth angle, and 3.0^o in terms of scan mirror azimuth angle. Figure 6.3.2 shows the HIRDLS boresight tangent point latitudes for two orbits. Figure 6.3.3 shows the boresight tangent point latitudes and longitudes for one day, the filled circles are for ascending orbits, and the open circles are for descending orbits. Fig. 6.3.4 shows the tangent point latitudinal and longitudinal differences of adjacent scans. It shows that the nominal $2.5^o x 2^o$ resolution of the medium resolution mode is achieved. As mentioned before, the $2.5^o x 2^o$ is the resolution close to equator, the longitudinal resolution at regions away from equator becomes increasingly larger as the poles are approached due to the use of fixed scan mirror azimuth step in the simulation. This problem will be fixed in the next version of the document. Details of the scan mirror and ILOS angles are listed in table 6.3.1. Also, the required scan mirror rate is higher due to the reduced vertical scan time of 6 seconds. It is now possible to have 3 vertical scans in each swath with BB view every other swath, and the vertical scan time can be made the same as in the global mode, which is 9.5 seconds. This will results in the same scan mirror rate as in the global mode. Three scans each swath and BB view every other swath (6 vertical scans between BB views, instead of the current 8 vertical scans between BB views) will be implemented in the next version of this document.

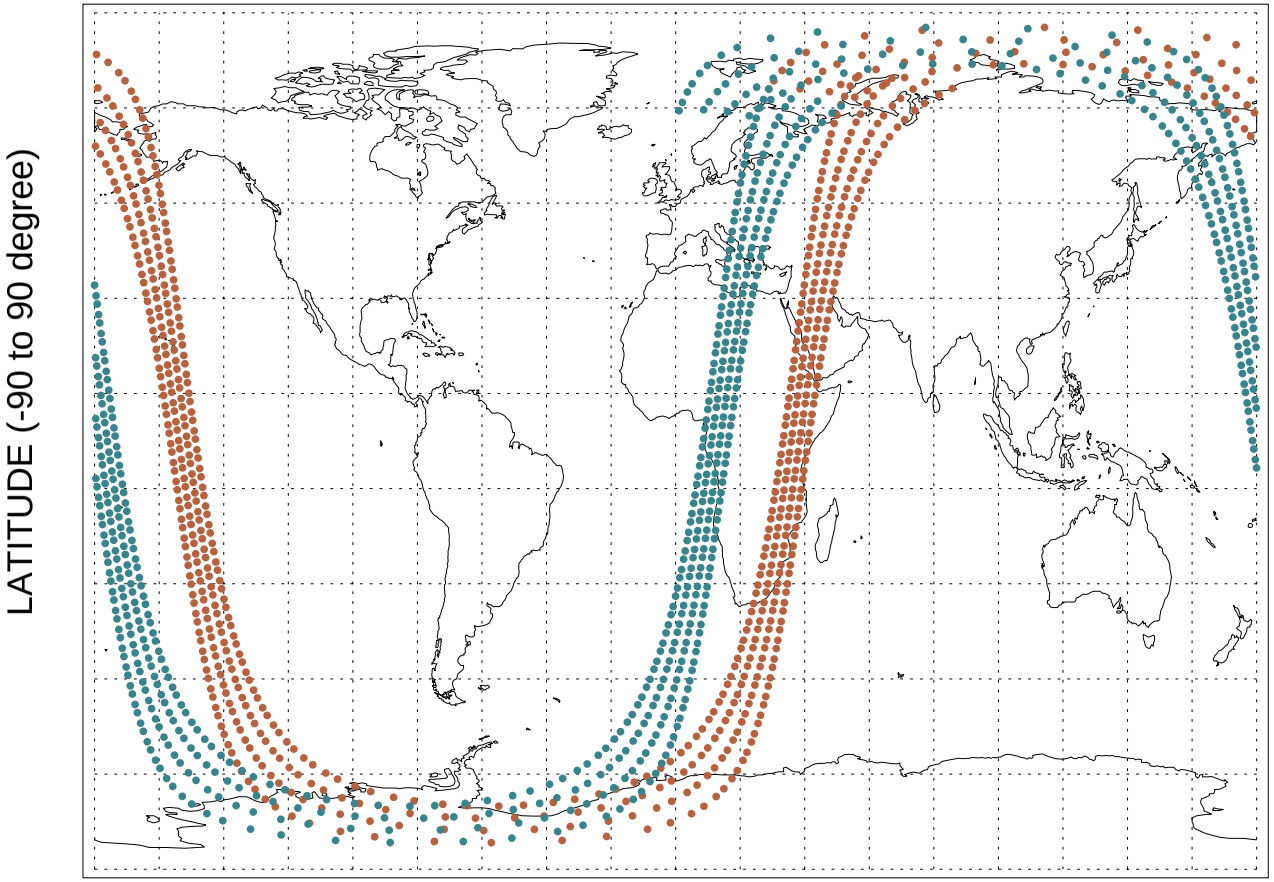
Conditions for the mode:	on command
Spatial resolution:	2.5^o x 2° at equator
ILOS elevation scan range:	23.264^o to 26.354^o (130 km to -30 km)
ILOS Azimuth scan range:	-12.0^o to 6.0^o
Scanner scan rate:	0.257^o/s - 0.259^o/s , 66 seconds for 2 swaths between BB view, 6.0 sec/scan
Maximum azimuth slew rate:	14.01^o/s (-12.054^o to 58.0^o in 5.0 s)
Maximum elevation slew rate:	0.679^o/s (25.3^o to 23.264^o in 3.0 s)



Note: 8 vertical scans in 2 swath between BB view.

Fig. 6.3.1 Medium resolution mode scan sequence diagram.

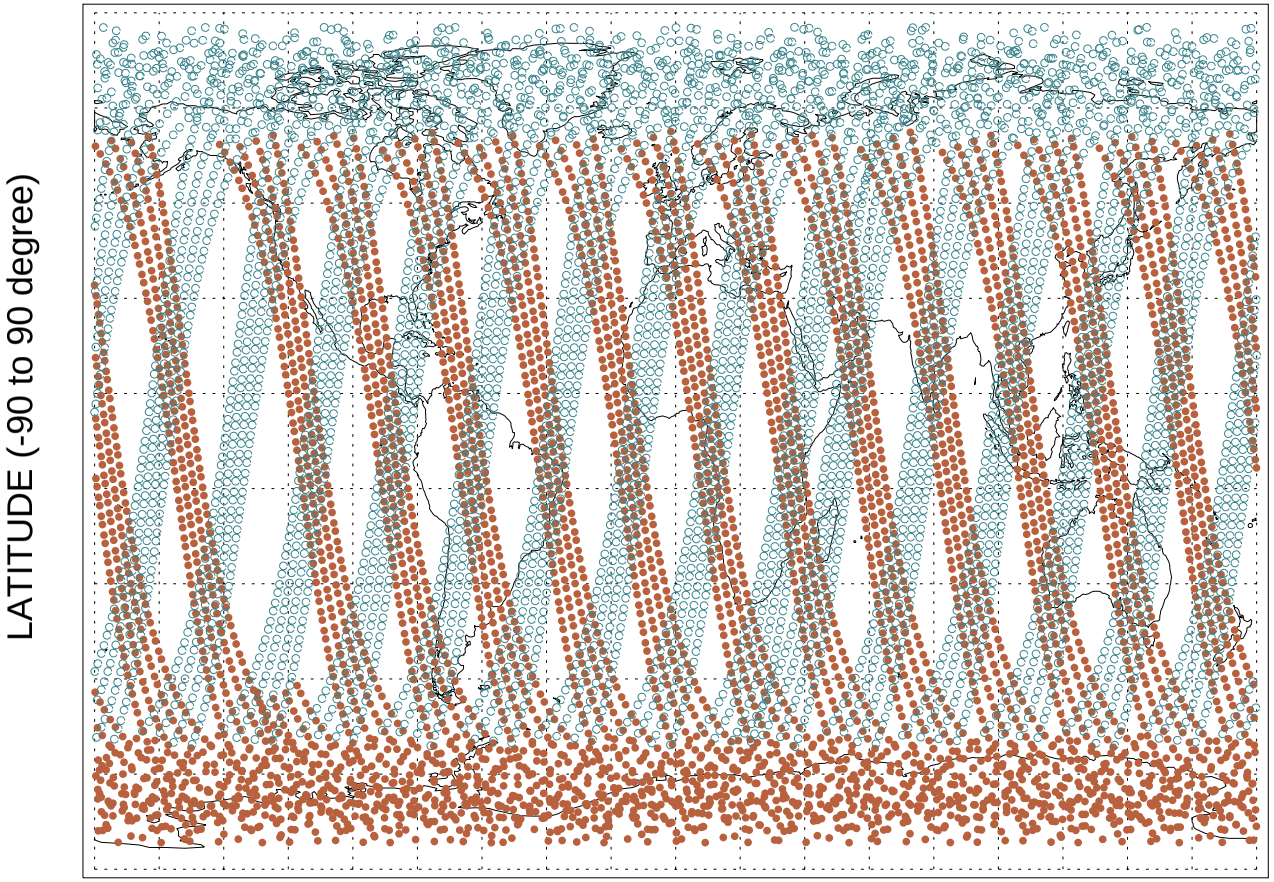
HIRDLS MEDIUM RESOLUTION MODE SUB-TANGENT POINT



EOS/PM orbit from SDP Toolkit
Starting time: 2003-01-01T00:00:00.000000
Time for 2 swaths between BB view: 66 sec; Single scan time: 6.0 sec
Coverage for two orbits (~200 minutes).ILOS azimuth range: -12 to 6 degree.

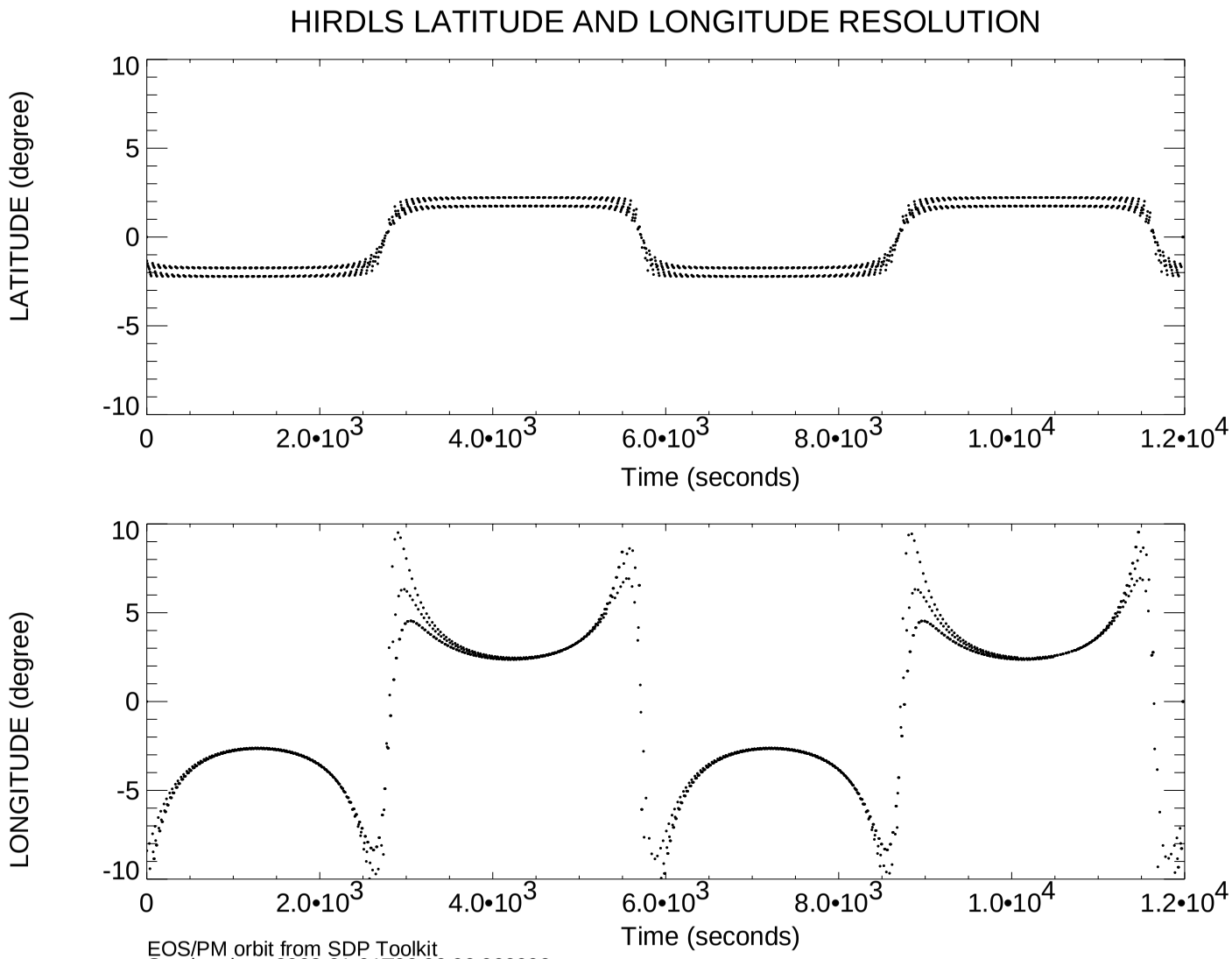
Fig. 6.3.2 HIRDLS boresight tangent point latitudes and longitudes in the Medium Resolution Mode.

HIRDLS MEDIUM RESOLUTION MODE SUB-TANGENT POINT



EOS/PM orbit from SDP Toolkit, coverage for one day(86,400 s)
Starting time: 2003-01-01T00:00:00.000000
Time for 2 waths between BB view: 66 sec; Single vertical scan time: 9.5 sec
ILOS azimuth range: -12 to 6 degree
Solid circle: ascending orbits; Open circle: descending orbits tangent points.

Fig. 6.3.3 HIRDLS boresight tangent point latitudes and longitudes in the Medium Resolution Mode for one day



EOS/PM orbit from SDP Toolkit
Starting time: 2003-01-01T00:00:00.000000
Time for 2 swath between BB view: 66 sec; Single vertical scan time: 6 sec
Global Mode coverage for two orbits (~200 minutes). ILOS azimuth range: -11 to 6 degree.

Fig. 6.3.4 HIRDLS latitude and longitude difference between two adjacent scans in the Medium Resolution Mode for two orbits.

Table 6.3.1 Detailed scan mirror and ILOS angles for medium resolution mode.

Assumptions:

1. Spherical Earth and constant S/C altitude approximation: R_E = 6367 km
   $R_{S/C}$ = 7072 km
2. ILOS lower tangent height: H_1 = -30 km
   ILOS upper tangent height: H_2 = 130 km
3. Single vertical scan: 6 s, 1st scan from top to bottom (H_2 to H_1)

Time (s)		**ILOS Elevation (degree)**		**ILOS Azimuth (degree)**		**Scan Mirror Elevation (degree)**		**Scan Mirror Azimuth (degree)**		**Mirror Scan Rate (deg/s)**
Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final	
Single elevation scan at zero azimuth angle										
0.0	6.0	23.264	26.354	0.00	0.00	-1.018	0.527	0.00	0.00	0.257
8 elevation scans in 2 swath (66 seconds)										
0.0	6.0	23.264	26.354	-11.904	-12.054	-1.023	0.530	-6.0	-6.0	0.259
7.0	13.0	26.354	23.264	-5.878	-6.103	0.528	-1.019	-3.0	-3.0	-0.258
14.0	20.0	23.264	26.354	0.000	0.000	-1.018	0.527	0.0	0.0	0.257
21.0	27.0	26.354	23.264	5.878	6.103	0.528	-1.019	3.0	3.0	-0.258
29.0	35.0	23.264	26.354	-11.904	-12.054	-1.023	0.530	-6.0	-6.0	0.259
36.0	42.0	26.354	23.264	-5.878	-6.103	0.528	-1.019	-3.0	-3.0	-0.258
43.0	49.0	23.264	26.354	0.000	0.000	-1.018	0.527	0.0	0.0	0.257
50.0	56.0	26.354	23.264	5.878	6.103	0.528	-1.019	3.0	3.0	-0.258

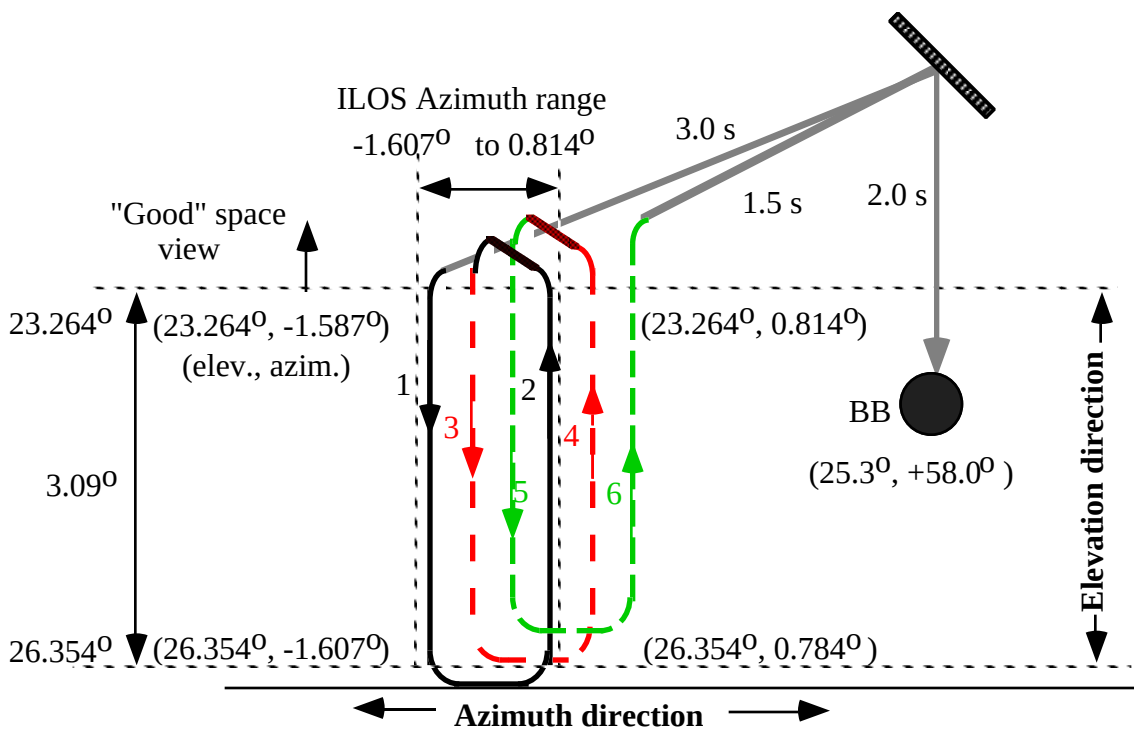
Note: The LOS scan rates are approximately 2 times those of the scan mirror scan rates.

6.4 High Resolution Mode ($1^o x 1^o$)

This mode allows even higher horizontal resolution data acquisition over the nominal vertical range and with nominal signal-to-noise. This again comes at the expense of large gaps between profiles on successive orbits. Possible applications are gravity wave studies, polar vortex boundary mapping, location of volcanic plumes soon after eruptions, location and properties of polar stratosphere clouds and possibly tropical cirrus. The swath resolution is ~1° in both the longitudinal and latitudinal directions. Caveats regarding use are the same as for the medium resolution mode. In the high resolution mode, the BB view is conducted every 3rd swath. As mentioned in section 6.3, this will lead to time savings and nonuniform latitude resolution. However, the nonuniform latitude resolution between different swath should have minimal impact on the use of the data collected in this mode.

The scan characteristics of the high resolution mode in terms of the two-axis scanner operation is described below. Details of the scan mirror and ILOS angles are listed in table 6.4.1. Figure 6.4.1 is a schematic diagram of the high resolution mode scan sequence. The ILOS azimuth scan range is from -1.6^o to 0.8^o, the time for 3 swaths between BB view is 66 seconds, and each vertical scan takes 9.5 seconds, and azimuthal slew from one vertical scan to the next within one swath takes 0.5 second, as in the global mode. Within one swath, the spacing between two adjacent scans is 2.4^o in terms of ILOS azimuth angle, and 1.2^o in terms of scan mirror azimuth angle. Figure 6.4.2 shows the HIRDLS boresight tangent point latitudes and longitudes in the high resolution mode for two orbits. Figure 6.4.3 shows the boresight tangent point latitudes and longitudes for one day, the filled circles are for ascending orbits, and the open circles are for descending orbits. Fig. 6.4.4 shows the tangent point latitudinal and longitudinal differences of adjacent scans. It shows that the nominal $1^o x 1^o$ resolution of the high resolution mode is achieved at the equator. As explained in the medium resolution mode, the longitudinal resolution becomes increasingly larger as the poles are approached due to the use of fixed scan mirror azimuth angle step in the simulation. This problem will be fixed in the next version of the document.

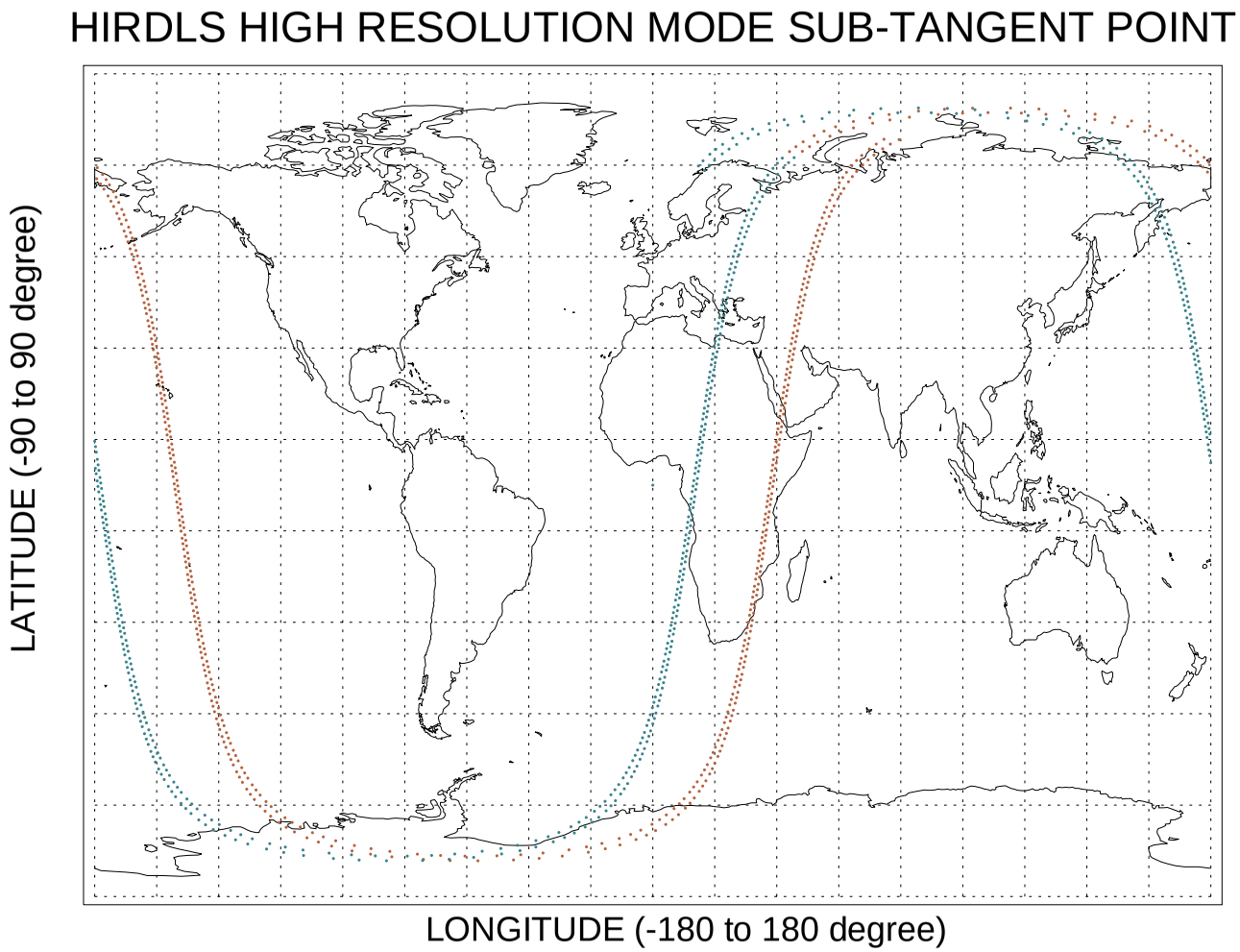
Conditions for the mode:	on command
Spatial resolution:	1° x 1° at equator
ILOS elevation scan range:	23.264^o to 26.354^o (130 km to -30 km)
ILOS Azimuth scan range:	-1.6^o to 0.8^o
Scanner scan rate:	0.163^o/s - 0.163^o/s , 66 seconds for 3 swath between BB view, 9.5 sec/scan
Maximum azimuth slew rate:	19.869^o/s (-1.607^o to 58.0^o in 3.0 s)
Maximum elevation slew rate:	1.357^o/s (25.3^o to 23.264^o in 1.5 s)



Note: 6 vertical scans in 3 swaths between BB view.

Fig. 6.4.1 High resolution mode scan sequence diagram.

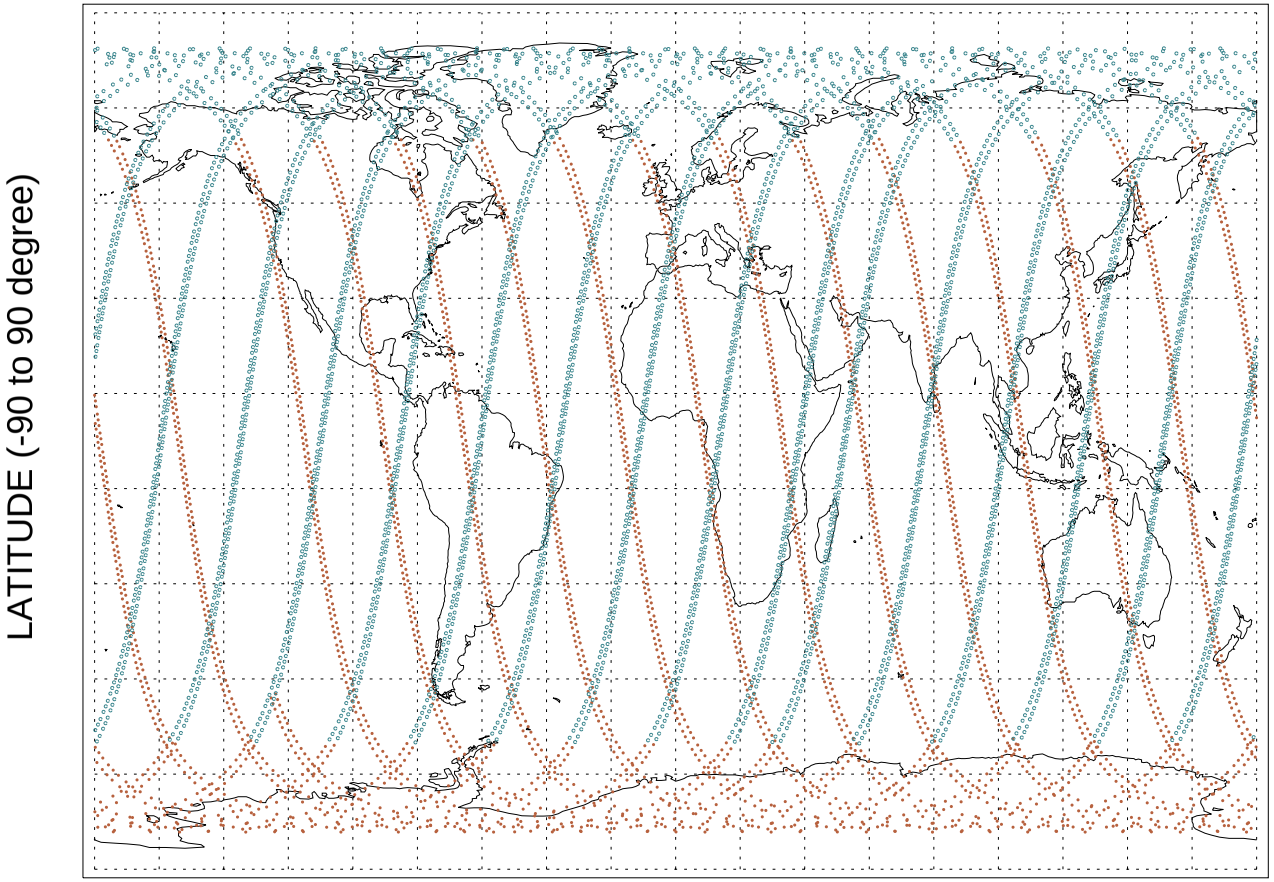
HIRDLS HIGH RESOLUTION MODE SUB-TANGENT POINT



EOS/PM orbit from SDP Toolkit
Starting time: 2003-01-01T00:00:00.000000
Time for 3 swaths between BB view: 66 sec; Single scan time: 9.5 sec
Coverage for two orbits (~200 minutes).ILOS azimuth range: -1.6 to 0.8 degree.

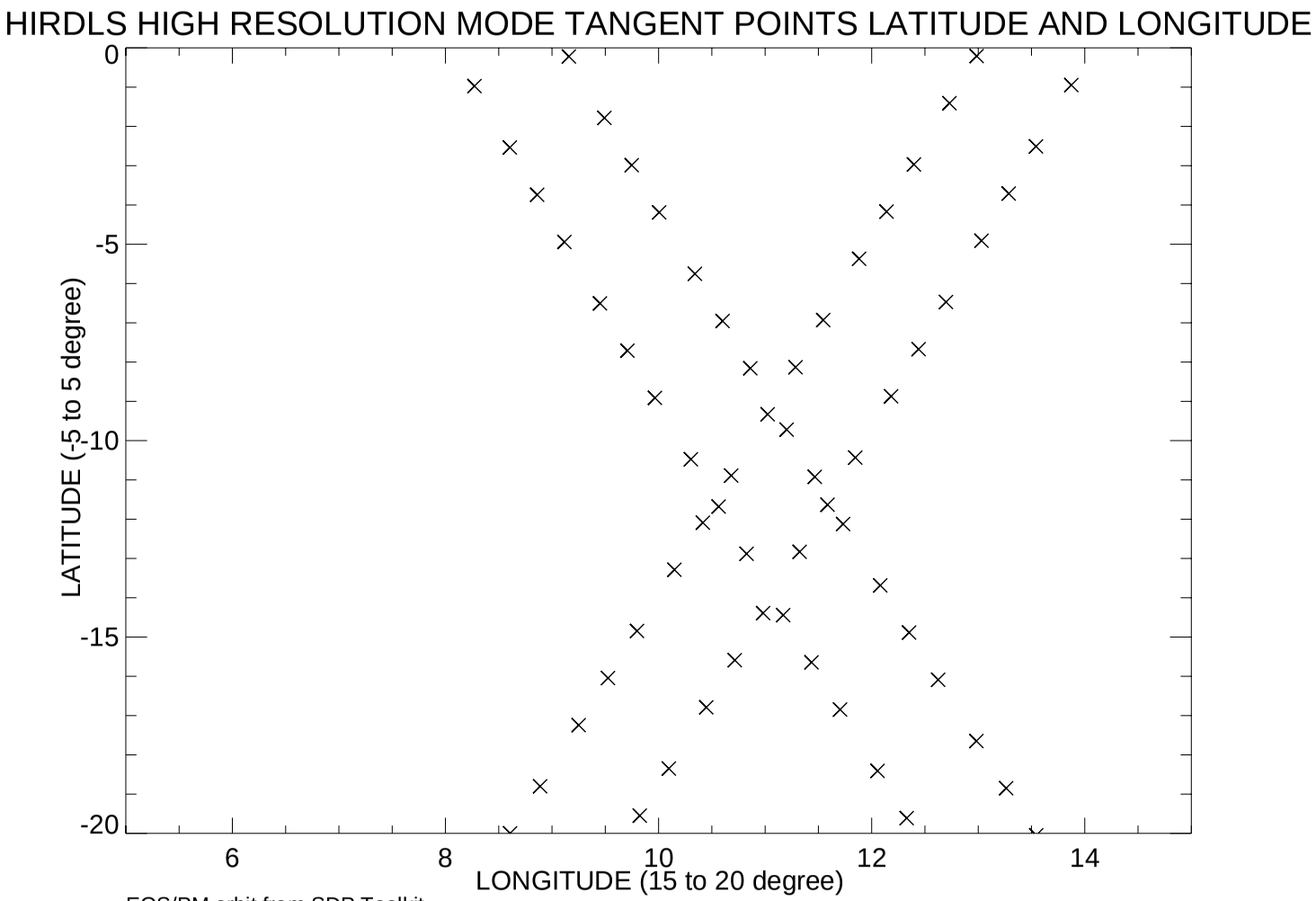
Fig. 6.4.2 HIRDLS boresight tangent points latitude and longitude in the High Resolution Mode.

HIRDLS HIGH RESOLUTION MODE SUB-TANGENT POINT



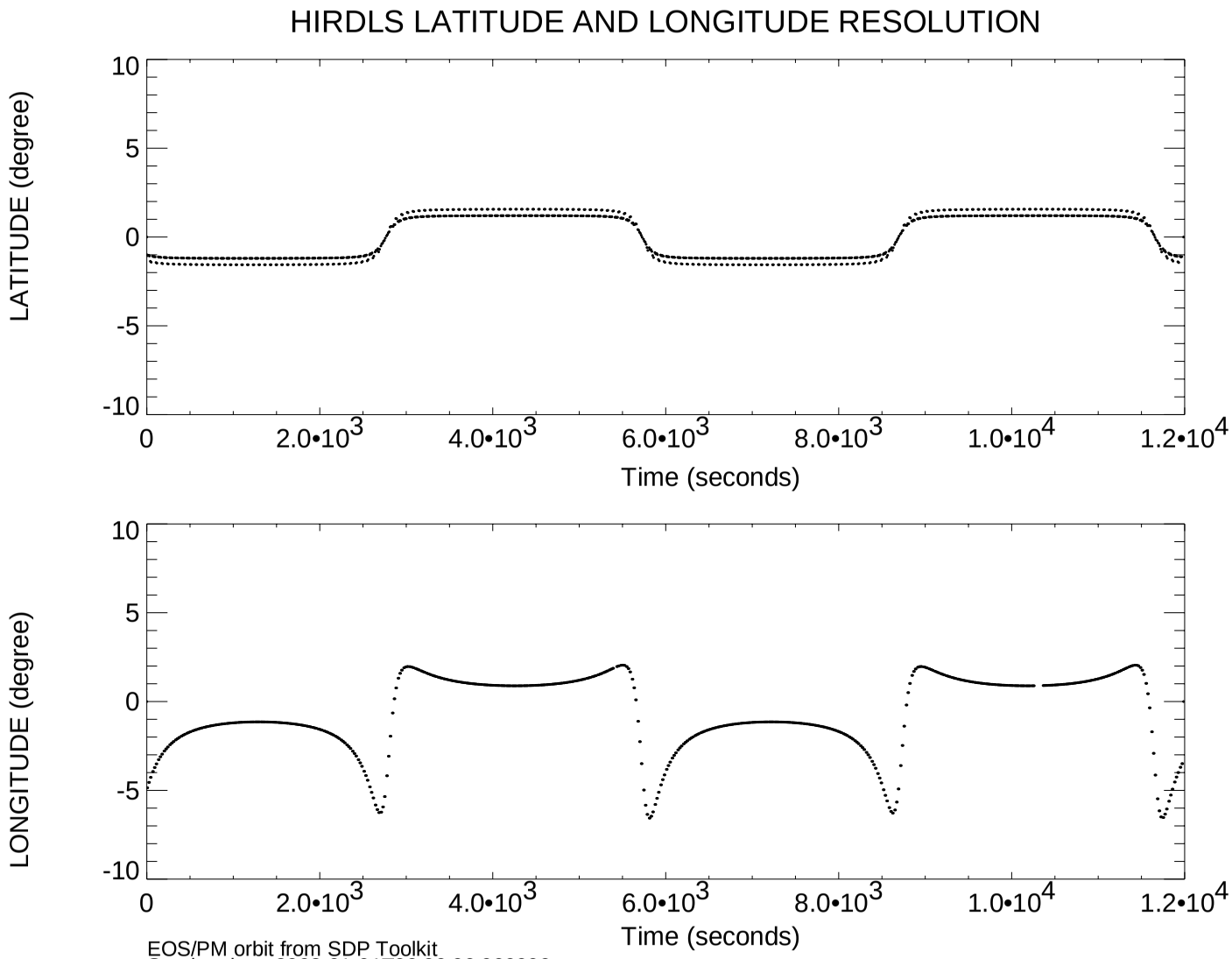
EOS/PM orbit from SDP Toolkit, coverage for one day(86,400 s)
Starting time: 2003-01-01T00:00:00.000000
Time for 3 swaths between BB view: 66 sec; Single vertical scan time: 9.5 sec
ILOS azimuth range: -1.6 to 0.8 degree
Solid circle: ascending orbits; Open circle: descending orbits tangent points.

Fig. 6.4.3 HIRDLS boresight tangent point latitudes and longitudes in the High Resolution Mode for one day



EOS/PM orbit from SDP Toolkit
Starting time: 2003-01-01T00:00:00.000000
Time for 3 swath between BB view: 66 sec; Single scan time: 9.5 sec
Coverage for two orbits (~200 minutes)in the Southern Hemisphere. ILOS azimuth range: -1.6 to 0.8 degree.

Fig. 6.4.4 Blow-up view of HIRDLS boresight tangent points latitude and longitude in the High Resolution Mode.



EOS/PM orbit from SDP Toolkit
Starting time: 2003-01-01T00:00:00.000000
Time for 3 swath between BB view: 66 sec; Single vertical scan time: 9.5 sec
Global Mode coverage for two orbits (~200 minutes). ILOS azimuth range: -1.6 to 0.8 degree.

Fig. 6.4.5 HIRDLS latitude and longitude difference between two adjacent scans in the High Resolution Mode for two orbits.

Table 6.4.1 Detailed scan mirror and ILOS angles for high resolution mode.

Assumptions:

1. Spherical Earth and constant S/C altitude approximation: R_E = 6367 km
   $R_{S/C}$ = 7072 km
2. ILOS lower tangent height: H_1 = -30 km
   ILOS upper tangent height: H_2 = 130 km
3. Single vertical scan: 9.5 s, 1st scan from top to bottom (H_2 to H_1)

Time (s)		**ILOS Elevation (degree)**		**ILOS Azimuth (degree)**		**Scan Mirror Elevation (degree)**		**Scan Mirror Azimuth (degree)**		**Mirror Scan Rate (deg/s)**
Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final	
Single elevation scan at zero azimuth angle										
0.0	9.5	23.264	26.354	0.00	0.00	-1.018	0.527	0.00	0.00	0.163
6 elevation scans in 3 swath between BB view										
0.0	9.5	23.264	26.354	-1.587	-1.607	-1.018	0.527	-0.8	-0.8	0.163
10.0	19.5	26.354	23.264	0.784	0.814	0.527	-1.018	0.4	0.4	-0.163
20.0	29.5	23.264	26.354	-1.587	-1.607	-1.018	0.527	-0.8	-0.8	0.163
30.0	39.5	26.354	23.264	0.784	0.814	0.527	-1.018	0.4	0.4	-0.163
40.0	49.5	23.264	26.354	-1.587	-1.607	-1.018	0.527	-0.8	-0.8	0.163
50.0	59.5	26.354	23.264	0.784	0.814	0.527	-1.018	0.4	0.4	-0.163

6.5 Gravity Wave Mode

To provide data at the highest possible vertical resolution for gravity wave studies, it will be necessary to remove as much of the IFOV as possible from the radiances by deconvolution. This in turn requires the highest signal-to-noise measurements possible. This will be achieved by viewing at a fixed azimuth in the orbit track and vertically scanning at the slowest rate. There is a trade-off between latitudinal resolution and vertical scan rate. On the one hand, it is desirable to have the slowest scan rate possible for IFOV deconvolution; on the other hand, slow scan rate leads to longer vertical scan time and lower latitudinal resolution. Use of this mode will require careful coordination to avoid conflicts with other mission goals.

The scan characteristics of the gravity wave mode in terms of the two-axis scanner operation is described below. Details of the scan mirror and ILOS angles are listed in table 6.5.1. Figure 6.5.1 is a schematic diagram of the gravity wave mode scan sequence. The scans are conducted at fixed azimuth of 0° , each vertical scan takes 29.0 seconds, azimuthal slew from vertical scan direction change within one swath takes 1.0 second, and the time for two swaths between BB view is 66 seconds. This leads to latitudinal resolution of 2° (~ 200 km). It might be more desirable to reduce the vertical scan time from 29.0 seconds to 14-15 seconds and have 4 vertical scans in each swath, which will result in 1° (~100 km) latitudinal resolution. There is also another approach for gravity wave mapping, instead of scanning in the elevation direction at a fixed azimuth angle, it is useful to scan in the azimuth direction at a fixed elevation angle. The High Resolution Doppler Imager (HRDI) on UARS recently introduced a new gravity wave mode to scan the airglow layer in the azimuth direction at a fixed elevation (or tangent height). Those issues will be examined in the next version of the document.

Conditions for the mode:	on command for gravity wave study.
Spatial resolution:	2° x 25°
ILOS elevation scan range:	23.264^o to 26.354^o (130 km to -30 km)
ILOS Azimuth scan range:	fixed azimuth (e.g. 0° azimuth)
Scanner scan rate:	0.053^o/s - 0.053^o/s , 66 seconds for one swath between BB view, 29.0 sec/scan
Maximum azimuth slew rate:	23.2^o/s (0° to 58.0^o in 2.5 s)
Maximum elevation slew rate:	0.814^o/s (25.3^o to 23.264^o in 2.5 s)

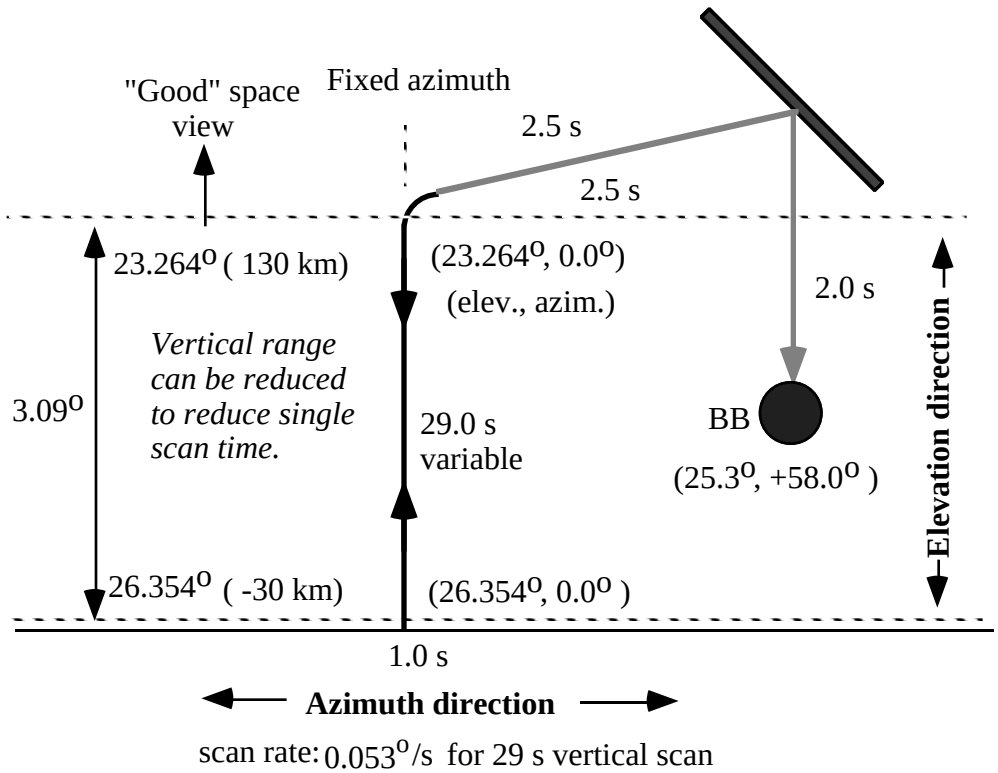


Fig. 6.5.1 Gravity wave mode scan sequence diagram.

Table 6.5.1 Detailed scan mirror and ILOS angles for gravity wave mode.

Assumptions:

1. Spherical Earth and constant S/C altitude approximation: R_E = 6367 km
   $R_{S/C}$ = 7072 km
2. ILOS lower tangent height: H_1 = -30 km
   ILOS upper tangent height: H_2 = 130 km
3. 1st scan from top to bottom (H_2 to H_1)

Time (s)		**ILOS Elevation (degree)**		**ILOS Azimuth (degree)**		**Scan Mirror Elevation (degree)**		**Scan Mirror Azimuth (degree)**		**Mirror Scan Rate (deg/s)**
Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final	
Single elevation scan at zero azimuth angle, single scan time T = 29 s. There are two vertical scan within one swath. Each swath takes 66 seconds.										
0.0	29.0	23.264	26.354	0.00	0.00	-1.018	0.527	0.00	0.00	0.053
30.0	59.0	26.354	22.264	0.00	0.00	0.527	-1.018	0.00	0.00	-0.053

6.6 Stratosphere-Troposphere Exchange(STE) Mode

This mode is for the observation of the upper troposphere and lower stratosphere (the middle world) with high horizontal and vertical resolution and signal-to-noise. These measurements will be made at the expense of vertical coverage. The high resolution data obtained in this mode will lead to better understanding of the mixing and transport between troposphere and the stratosphere. Much of this transport takes place at specific geographic locations during particular meteorological events at certain times of the year. Careful planning will be necessary to effectively exploit this mode in coordination with global observations.

The scan characteristics of the stratosphere-troposphere exchange mode in terms of the two-axis scanner operation is described below. Details of the scan mirror and ILOS angles are listed in table 6.6.1. Figure 6.6.1 is a schematic diagram of the stratosphere-troposphere exchange mode scan sequence. The current operation scheme leads to short vertical scan time and high mirror scan rate (~ 0.31°/s). It is possible to have BB view every two swaths and 3 vertical scans in each swath as in the medium resolution mode, this will result in longer vertical scan time and lower mirror scan rate as desired. This approach will be discussed in the next version of this document. More discussion among the HIRDLS team as to the extent of the vertical scans, desired latitudinal and longitudinal resolutions, regions of most interest for the STE modes, will be useful to better define the STE mode.

Conditions for the mode:	Low latitude, on demand.
Spatial resolution:	2° x 1°
ILOS elevation scan range:	23.264^o to 26.354^o(130 km to -30 km) for long scan. 24.809^o to 26.354^o for short scans.
ILOS Azimuth scan range:	-9.6^o to 4.8^o
Scanner scan rate:	0.309^o/s - 0.310^o/s , 22 seconds for one swath between BB view, 2.5 s per short scan, 5.0 s per long scan
Maximum azimuth slew rate:	22.55^o/s (-9.643^o to 58.0^o in 3.0 s)
Maximum elevation slew rate:	0.164^o/s (25.3^o to 24.809^o in 3.0 s)

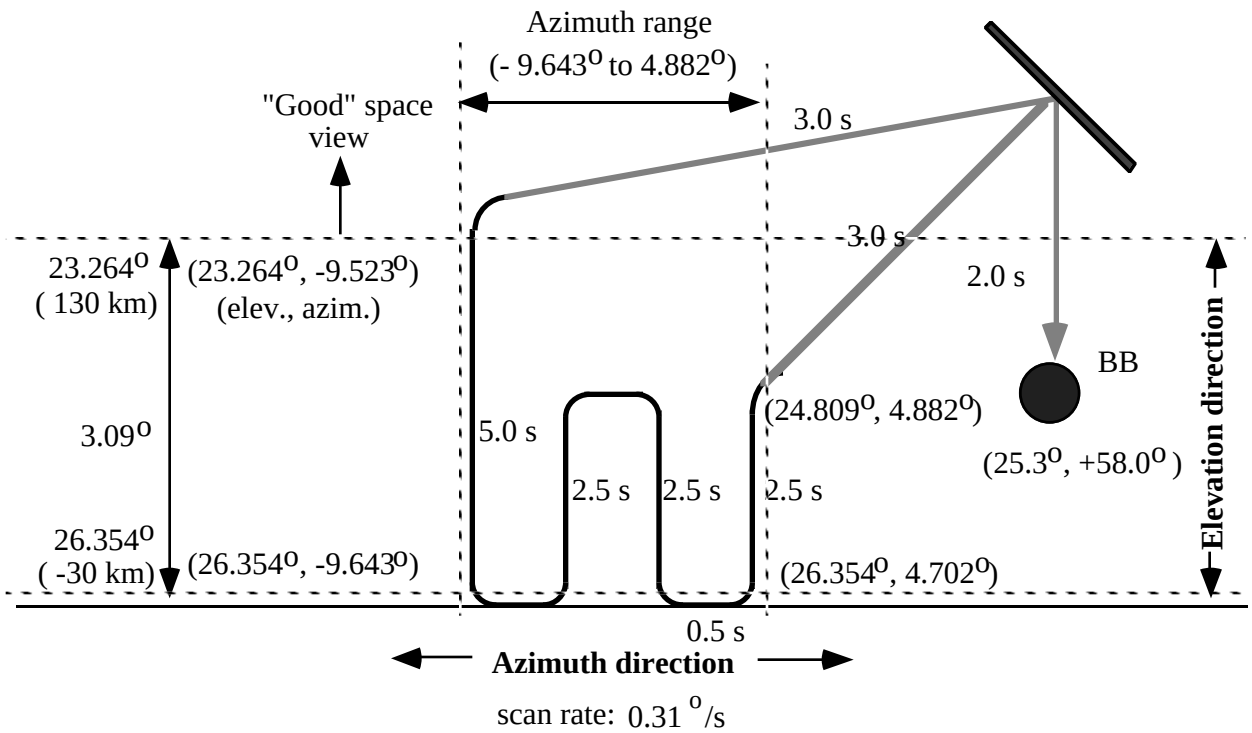


Fig. 6.6.1 Stratosphere-troposphere exchange mode scan sequence diagram.

Table 6.6.1 Detailed scan mirror and ILOS angles for STE mode.

Assumptions:

1. Spherical Earth and constant S/C altitude approximation: R_E = 6367 km
   $R_{S/C}$ = 7072 km
2. ILOS lower tangent height: H_1 = -30 km
   ILOS upper tangent height: H_2 = 130 km
3. Single vertical scan: 2.5 s per short scan, 5.0 s for long scan.
   1st scan from top to bottom (H_2 to H_1)

Time (s)		**ILOS Elevation (degree)**		**ILOS Azimuth (degree)**		**Scan Mirror Elevation (degree)**		**Scan Mirror Azimuth (degree)**		**Mirror Scan Rate (deg/s)**
Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final	
Single elevation scan at zero azimuth angle										
0.0	2.5	24.809	26.354	0.00	0.00	-1.018	0.527	0.00	0.00	0.309
3 short vertical scan and 1 long vertical scan in one swath										
0.0	2.5	24.809	26.354	-9.523	-9.643	-1.021	0.529	-4.8	-4.8	0.310
3.0	5.5	26.354	24.809	-4.702	-4.882	0.527	-1.019	-2.4	-2.4	-0.309
6.0	8.5	24.809	26.354	0.000	0.000	-1.018	0.527	0.0	0.0	0.309
9.0	14.0	26.354	23.264	4.702	4.882	0.527	-1.019	2.4	2.4	-0.309

6.7 Selected Target Mode

At times, it may be necessary to view certain Earth fixed targets as frequently as possible. Examples of such targets might be volcanoes in the early stage of eruption, formation of polar stratospheric clouds over mountain ranges in the polar regions, and ground sites where correlative measurements or field programs are being carried out. At middle and high latitudes, such targets come into the HIRDLS field of regard several (to many) times each day. To do this will require pre-planning and interruption of normal scanning for short periods of time while the scanner is directed to the appropriate azimuth angle. Once the selected target has been scanned, normal mode scanning will resume.

6.8 Mode Changes and Operating Sequences

Mode changes within a single orbit are anticipated for some scientific investigations. A possible scenario is presented here as an example.

Table 6.8.1 An example of mode changes and operating sequence within an orbit.

Orbit	Tangent Point Latitude (degree)	HIRDLS Mode
Ascending	0 - 30	Strat-Trop Exchange Mode
	30 - 60	Global Mode
	60 - 70	Medium Resolution Mode
	70 - 81	Alternative Global Mode
Descending	81 - 81 S	Global Mode
Ascending	81 S - 60 S	Gravity Wave Mode
	60 S - 0	Strat-Trop Exchange Mode