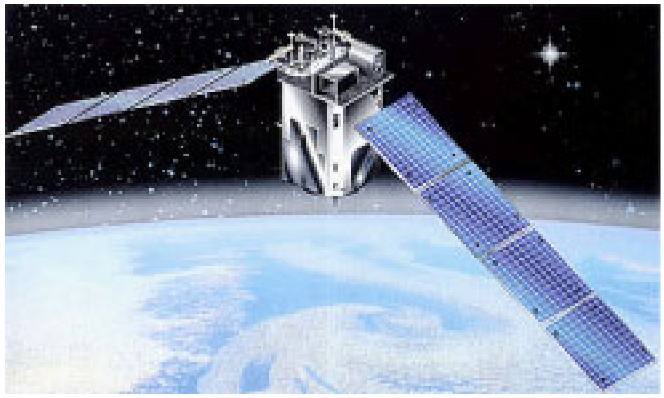
TIMED DOPPLER INTERFEROMETER



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1. Overview

1.1 TIMED Overview

Thermosphere • Ionosphere • Mesosphere • Energetics and Dynamics (TIMED) is the first science mission in the Solar Terrestrial Probe Program detailed in NASA's 1994 Strategic Plan. TIMED will explore Earth's Mesosphere and Lower Thermosphere/Ionosphere (MLTI) (60-180 km), the least explored and least understood region of our atmosphere. It is known that the global structure of this region can be perturbed during stratospheric warming and solar-terrestrial events, but the overall structure and dynamics responses of these effects are not understood. Advances in remote sensing technology employed by TIMED instrumentation enable us to explore this region on a global basis from space. A strong collaboration with ground-based instrumentation is planned.

TIMED is part of NASA's initiative to lower mission costs and provide more frequent access to space. The TIMED Spacecraft and instruments were launched along with the CNES/NASA Jason-1 Spacecraft, on-board a Delta-II ELV, from the Vandenberg Air Force Base, December 7, 2001. TIMED is managed for NASA by The Johns Hopkins University Applied Physics Laboratory, Laurel, Maryland.

The primary objective of the TIMED mission is to investigate and understand the energetics of the MLTI region. The MLTI is a region in which energetic solar radiation is absorbed, energy input from the aurora maximizes, intense electrical currents flow, and upwardly propagating waves and tides break. Yet, this region has never been the subject of a comprehensive, long-term, global investigation. Together with simultaneous ground-based observations, TIMED will provide for the first time a core subset of measurements defining the basic states of the MLTI region and its thermal balance.

The specific TIMED Mission Goals are:

• To determine the pressure, temperature, density, and wind structure in the MLTI region, including seasonal and latitudinal variations.

• To determine the relative importance of various radiative, chemical, electrodynamical, and dynamical sources and sinks of energy for the thermal structure of the MLTI.

TIMED measurements will be important for understanding the basic processes involved in the energy distribution of this region and the impact of natural and anthropogenic variations. In a society increasingly dependent upon satellite technology and communications, it is vital to understand atmospheric variability so its effects on satellite tracking, spacecraft lifetimes, degradation of materials, and re-entry of piloted vehicles can be predicted. The mesosphere may also show evidence of anthropogenic effects that could herald global-scale environmental changes. TIMED will characterize this region to establish a baseline for future investigations of global change.

1.2 TIDI Overview

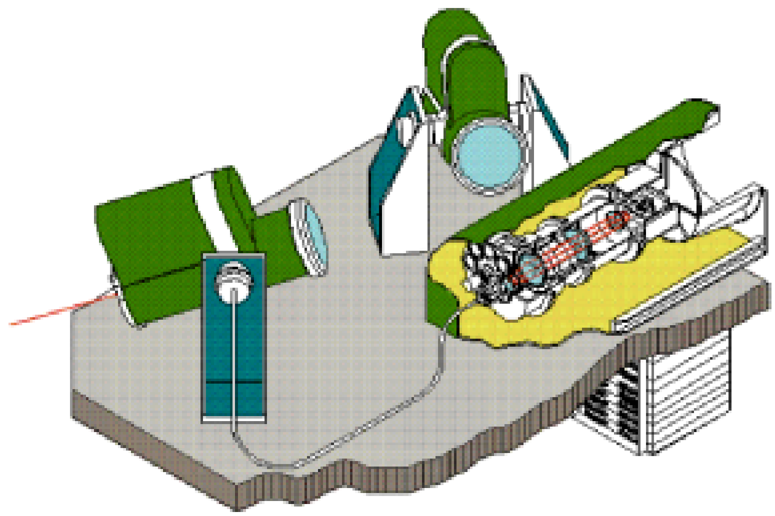
The TIMED Doppler Interferometer (TIDI) will investigate the dynamics and energetics of Earth's mesosphere and lower-thermosphere-ionosphere (MLTI) from an altitude of 60-300 km. TIDI measurements will allow us to obtain a global description of the vector wind and temperature fields, as well as important information on gravity waves, species densities, airglow and auroral emission rates, noctilucent clouds, and ion drifts. TIDI will provide basic information about global winds and temperatures. TIDI will also contribute to the study of MLTI energetics.

The TIDI interferometer (or Profiler) primarily measures horizontal vector winds and neutral temperatures from 60 to 300 km, with a vertical resolution ~2 km at the lower altitudes and with accuracies that approach ~3 m/sec and ~2 K, respectively, under optimum viewing conditions. The TIDI design allows for 100% duty cycle instrument operation during daytime, nighttime, and in auroral conditions. TIDI views emissions from OI 557.7 nm, OI 630.0 nm, OII 732.0 nm, O_2 At (0-0), O_2 At (0-1), Na D, OI 844.6 nm, and OH Meinel (9-4) and (7-3) to determine Doppler wind and temperature throughout the TIMED altitude range. TIDI also makes spectral ratio observations to determine O_2 densities and rotational temperatures.

- **Instrument Description**

TIDI consists of three major subsystems: four identical telescopes, a Fabry-Perot interferometer with a CCD detector, and an electronics box. Light from the selected regions of the atmosphere is collected by the telescopes and fiber-optically coupled to the detection optics. The four fields of view are scrambled along with a calibration input and converted to an array of five concentric circular wedges. This input then passes through a selected filter, then through a Fabry-Perot etalon, and is finally imaged onto a CCD via a circle-to-line imaging optic (CLIO) device.

Figure 1. TIDI layout
(showing two of four telescopes).



- **TIDI System**

Mass:	41.8 kg
Electrical Power:	19.32 watts (orbit average)
Heater Power:	11.0 watts
Data Rate:	2494 bits/sec
Observations:	winds, temperatures, and density
Wind Accuracy:	3 m/s (line of sight)
Altitude Resolution:	2 km
Spectral Range:	550-900 nm
Lifetime:	>2 years

- **Electronics System**

Hybrid Power supply
80C51 (UTMC) Flight computer
Data acquisition
CCD controller
Filter wheel/ shutters/ PWM heaters
Telescope servo amp
Calibration lamp power supply

- **Telescope Specifications**

Off axis Gregorian
Low scatter optics and baffles
Zenith gimbal

Clear Aperture	7.5 cm
Area	44.2 cm^2
Angular FOV	2.5° horizontal x 0.05° vertical
F/number	2.2

- **Profiler Specifications**

Fixed gap single etalon
Fabry-Perot interferometer
2 x 8 position filter wheel
Circle-to-line image converter (CLIO)
Passively Cooled CCD detector
5 x 32 Channels

Clear Aperture	7.5 cm
Plate Diameter	10.5 cm
Gap	2.2 cm
Finesse	8.1-8.9

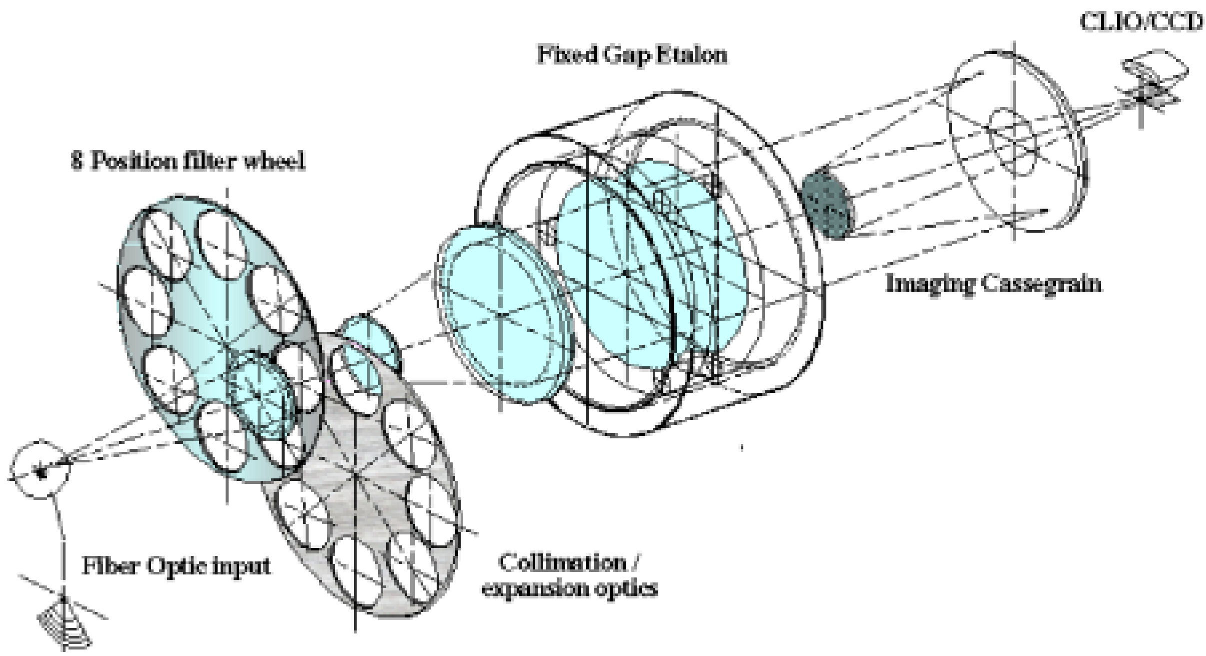


Figure 2. Profiler Layout

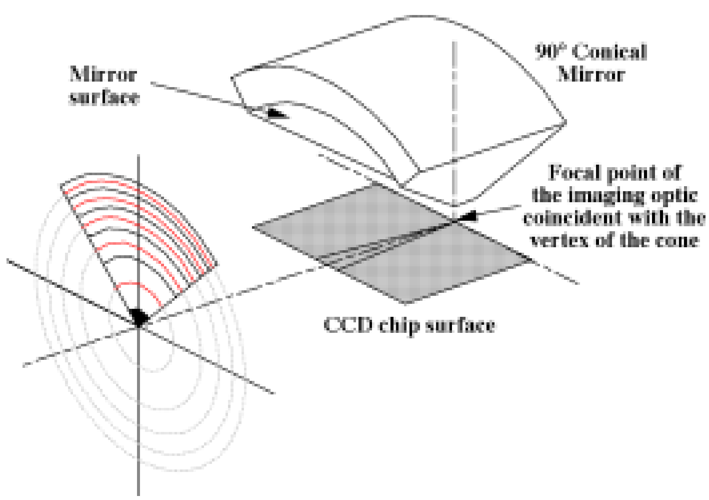


Figure 3. Detector Layout

2. TIDI Data Acquisition Summary

The TIDI telescopes perform limb scans through the terrestrial airglow layers throughout the satellite orbit. TIDI obtains these scans simultaneously in four orthogonal directions: two at 45° forward but on either side of the satellite's velocity vector and two at 45° rearward of the satellite. These four views provide the measurements necessary to construct the horizontally resolved vector winds as a function of altitude within the MLTI region along two parallel tracks, one on either side of the spacecraft. Each vertical scan consists of individual views 2.5° (horizontal, along the limb) by 0.05° (vertical, normal to the limb) in angular size. The vertical altitude resolution of the instrument is 2.5 km, but the altitude spacing between views will be adjusted to yield a measurement vertical resolution of half a scale height throughout the limb scan. The altitude step size will range from 2.5 km in the MLTI region to 25 km in the thermosphere. Each up/down acquisition cycle will take 100-200 seconds to complete, resulting in a nominal horizontal spacing between profiles of approximately 750 km along the orbit track. The exact time per vertical scan will depend on the mode being run and the integration or dwell time needed at each altitude step. Each up/down scan cycles through a sequence of filter tunings, selecting the optimal emissions to be viewed within each altitude range to allow rotational and/or Doppler temperatures as well as neutral winds to be retrieved. More information about the dayside and nightside science modes being planned and their estimated accuracy (wind errors) as a function of altitude is given below in the TIDI Science Measurement Summary.

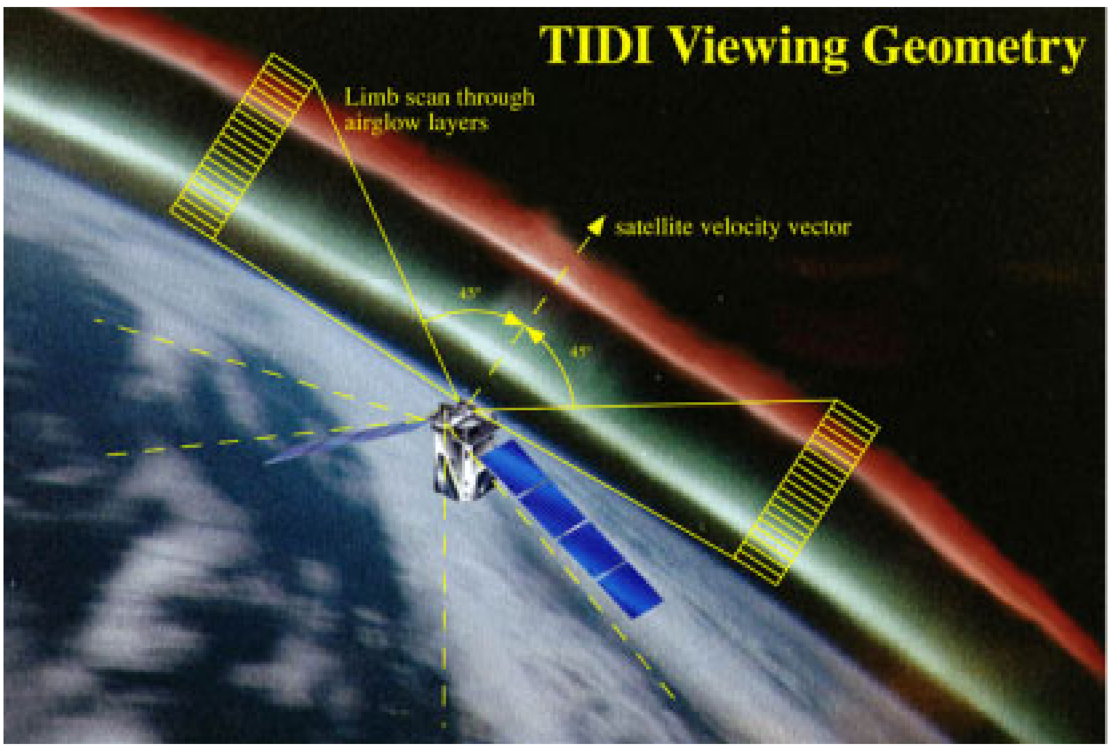


Figure 4. Illustration of TIDI viewing geometry

3. TIDI Coverage

The precession rate of TIMED is such that it will take 60 days to precess 12 hours in local time (3° per day). On any given day there is little change in local solar time coverage at low and mid-latitudes. The most useful parameter for describing the TIDI local time coverage and viewing geometry is the solar beta angle, the complement of the angle between the normal to TIMED's orbital plane and the earth-sun line. If the solar beta angle is 90°, then the normal to the orbital plane is parallel to the earth-sun line. If the solar beta angle is 0°, then the normal to the orbital plane is perpendicular to the earth-sun line. The variation in solar beta angle through the first two years of the TIMED mission is shown in Figure 5.

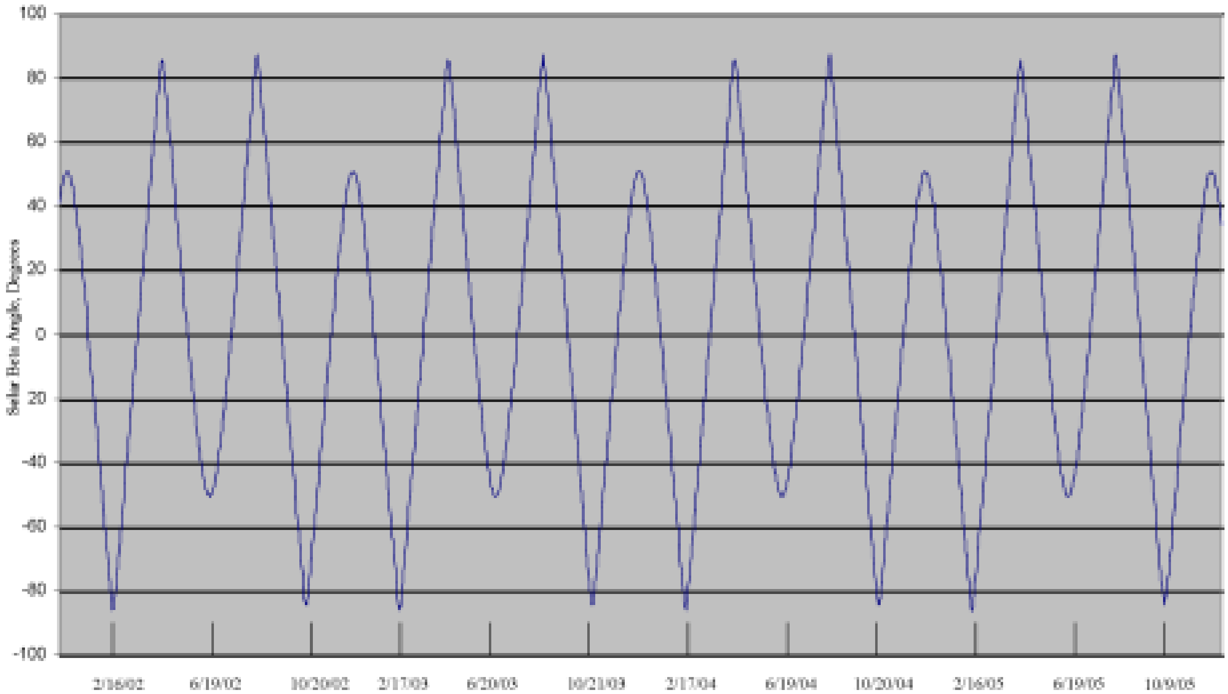


Figure 5. TIMED solar beta angle variation since launch and predicted out to December 2005

The transition between TIDI dayside and nightside modes of observation is made when the solar zenith angle (SZA) at the spacecraft reaches 90°. The solar scattering angle, the angle between the line of sight to the tangent position and the sun, creates a secondary but crucial consideration in the instrument operation. A TIDI telescope will not perform observations if the solar scattering angle is less than 15°, that is if the direction to the sun is within 15° to the direction of the tangent position. This sun-avoidance criterion prevents TIDI from directly viewing the sun. As long as the solar scattering angle is acceptable (>15°), TIDI will seamlessly continue data acquisition during the transition between day and night, as the spacecraft passes through 90° in solar zenith angle. It is possible for any number of the four tangent points (from none to all four) to be in twilight at a given moment. The TIDI data inversion technique becomes less successful when the tangent point viewed by a TIDI telescope is in twilight. For twilight views, only line of sight data products (Level 1 data) will be available; inversion products (Level 2 data, such as altitude profiles of the neutral horizontal winds) will not be produced.

Consequently, optimum TIDI daytime observations are performed when:

• the solar zenith angle at the tangent point is less than 80°
• the solar zenith angle at the spacecraft is less than 90°
• the solar scattering angle is greater than 15°

Nighttime observations are performed when:

• the solar zenith angle at the tangent point is greater than 100°
• the solar zenith angle at the spacecraft is greater than 90°
• the solar scattering angle is greater than 15°

Figure 6 describes the relationship between the solar beta angle, the solar scattering angle, daytime/nighttime observations and TIDI coverage for a representative orbits.

• symbols represent the local solar time/latitude of the tangent point at 100 km altitude
• the hatched area corresponds to night; clear to day
• the dashed lines indicate the boundaries of twilight (defined by the tangent point solar zenith angle being SZA = 90° ± 10°)
• daytime observations are represented by solid symbols; nighttime by open symbols
• red diamonds represent tangent points on the sun-side (warm side); blue hexagons are anti-sun-side (cold side) of the spacecraft

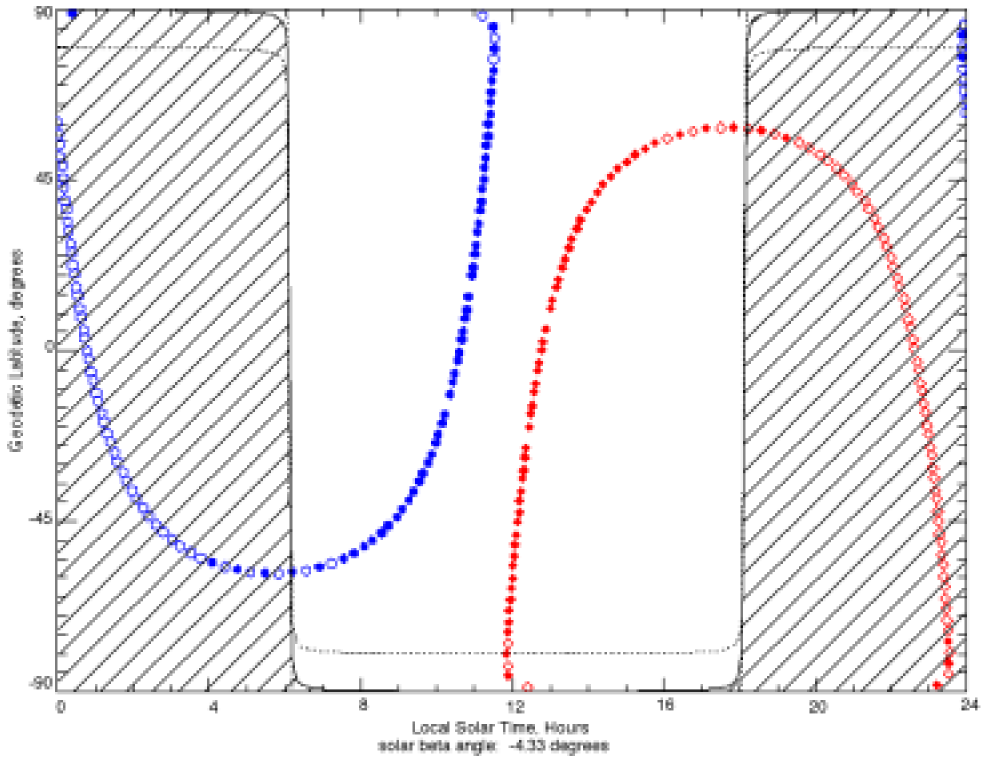


Figure 6. TIDI coverage at equinox, β angle near 0.

The TIMED orbit (inclination 74°) combined with the four set azimuth angles of the limb-directed TIDI telescopes implies that there are two 'turnaround' latitude circles where the density of data acquisition reaches a maximum value. For an altitude of 80 km, these latitudes are roughly ± 58° and ± 90°.

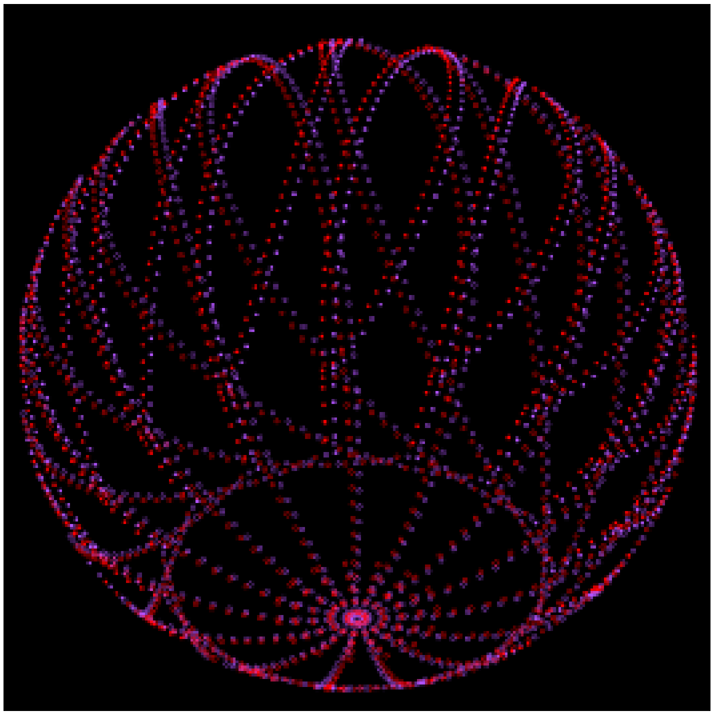


Figure 7. TIDI warm (blue) and cold (red) side tangent locations for a representative day, shown overlaying the globe. TIMED performs at least 14 complete orbits per day.

4. TIDI Science Measurement Summary

Basic TIDI science modes are listed in the following tables:

Table 1. Summary of TIDI Operational Modes

Day Scan Table	*Night Scan Table*	*Comments*
12100	14301	Normal Low Beta Science
12000	14301	Normal Mid Beta Science

Table 2. Scan Table Definitions

Mode #	*Type*	*Emissions*	*Altitude Range & Intervals (km)*	*Integration Times (s)*
12100	Day	O_2(0-0)P9, O_2(0-0)P15, O(^1S)	60–180 @1.25–10	0.75
12000	Day	O_2(0-0)P9, O_2(0-0)P15, O(^1S)	60–180 @1.25–10	1.0
14301	Night	O_2(0-0)P9, O(^1S)	80–110 @1.25–2.5	3.0