MODIS DATA STUDY TEAM PRESENTATION

August 4, 1989

AGENDA

1. Study Plan for the MODIS Data Study Team.
2. Ray Tracing Calculations of Atmospheric Effects.
3. Using the Ray Tracing Program to Estimate Other Errors in the MODIS Data Processing.
4. Notes on a Conversation with John Barker.
5. Spreadsheet to Compute MODIS Data Rates.

STUDY PLAN FOR THE MODIS DATA STUDY TEAM: AUGUST 1989 TO MARCH 1990
DRAFT - July 25, 1989

AUGUST/SEPTEMBER

Work for the MODIS Data Study Team during August and September is anticipated to center on the detailed analysis of the proposed core data products and their respective algorithms. A limited number of Level-2 through Level-4 MODIS data products have been identified by the MODIS science team as being core/at-launch standard MODIS data products. A preliminary list of these core products was distributed in June 1989 in the "MODIS Science Data Product Summary Document" and subsequently presented to the MODIS Science Team at the July 5-7 team meeting. The science team split into three discipline sessions (ocean, atmosphere, and terrestrial) and refined the core product list, which was distributed at the July 14 MODIS Data Study Team presentation. On the order of 40 products have been designated for core data product generation at Level-2 and above.

These requirements development tasks will involve a series of meetings with each of the three MODIS discipline leaders at GSFC (Wayne Esaias, Chris Justice, and Mike King). The following two deliverables will summarize the information collected during this period: (1) the "Preliminary MODIS Core Data Product Analysis Report" and (2) the Preliminary MODIS Core Data Product Algorithm Report."

OCTOBER

During the month of October, the MODIS Data Study Team will revise the Data Acquisition and Processing Scenario document previously delivered and distributed to the MODIS Science Team. The revisions will center about updating the document to reflect the latest information regarding core product generation. A goal will be a complete and accurate data path from all required input data and Level-0/1 MODIS data through the completion of all proposed core products. Also to be refined will be a timetable of software delivery and implementation dates consistent with EosDIS guidelines. The conceptual schedule presented to the MODIS Science Team on July 6 will be used as a starting point. This research will be summarized in the following deliverable: the "MODIS Core Data Product Processing Scenario Document."

NOVEMBER

During the month of November, the MODIS Data Study Team will concentrate on preparing a presentation for the MODIS Science Team Meeting and supporting preparations for the meeting. There is a good possibility that the meeting will not be held in November. If this is the case, then the study team's efforts will be spent on developing a scenario for non-core standard product processing. In particular, the effort will address the implementation of new standard products some time after the projected October 1996 launch of Eos-A. Reprocessing, input data, scheduling, and product inter-relationship issues will be considered. The research will be summarized in one of the two following deliverables: (1) "MODIS Science Team Meeting Presentation/Support" or (2) "MODIS Post-Launch Data Product Processing Scenario Document."

DECEMBER

During the month of December, the MODIS Data Study Team will consider the requirements of the core utility and support algorithms. In particular, the calibration, Earth location, cloud identification, atmospheric correction, surface incident solar spectral radiation, time and space averaging, and display algorithms will be analyzed in depth. The detailed interrelationships between the MODIS core and R&D (post-launch) standard products and the utility algorithms will be defined. The results of the analysis will be summarized in the delivery of the "Utility/Support Algorithm Requirements Document."

An additional deliverable for the end of December will be a "MODIS Processing and Storage Requirements on CDHF Document." This document will summarize the CPU, storage, and memory requirements for MODIS core standard product generation, utility routines operation, and also for the extended TMCF (for algorithm development and validation) within the CDHF. A goal will be confidence in the estimates to a factor of two. A statement of confidence on the estimates will be supplied.

JANUARY

During the month of January, the MODIS Data Study Team will emphasize the functional and performance requirements of the MODIS Science Data Support Team (SDST) and the MODIS Instrument Characterization Team (ICT). The specific requirements for instrument monitoring, calibration maintenance, and data for the individual ICT members will be considered. The strategy for preparation and optimization of team members' algorithms prior to delivery to the CDHF for implementation will be addressed. Implications and requirements related to the use of simulated MODIS data sets will be compiled. The month will close with the following deliverable: the "MODIS SDST/ICT Requirements Document."

FEBRUARY

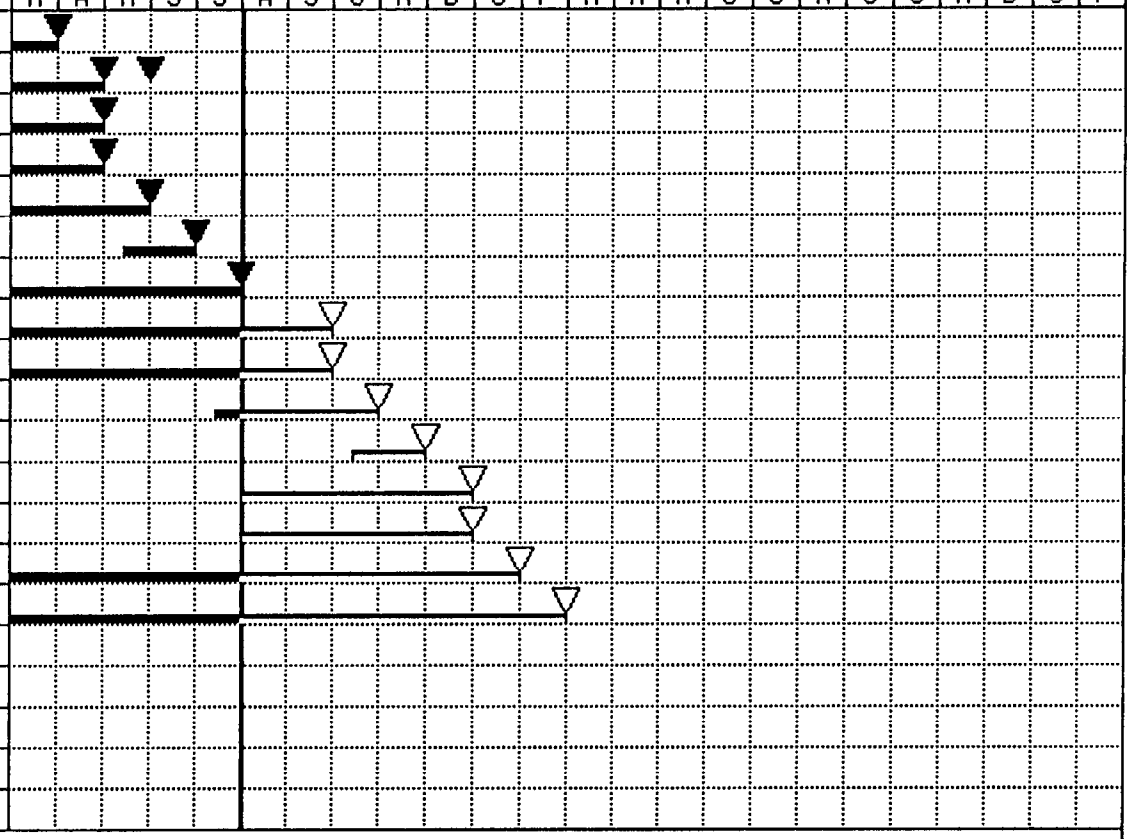
During the month of February, the MODIS Data Study Team will combine the requirements of the core utility and support algorithms, the core data product algorithms, the ICT and SDST requirements, and the Core and post-launch scenario documents to present an integrated picture of the core MODIS data requirements prior to launch, at launch, and shortly after launch. The results will be delivered in the "MODIS Core Data Product Requirements Document."

MODIS DATA SYSTEM STUDY
APPROVAL
ACCOMP.

Summary of Deliverables

ORIG. APPVL. 06/24/88
LAST CHANGE 08/01/89
STATUS AS OF 08/01/89

	MILESTONES
01	Prel Data Requirements Doc
02	Non-Advocacy Review Materials
03	EosDIS/MIDACS I/F Comparison
04	Scenarios for Science Team
05	Prel TM Sci Prod Summary
06	Support MODIS Science Team Mtg
07	Input Data Attributes Report
08	Prel Core Prod Algorithm Rep
09	Prel TM Core Prod Analysis Rep
10	Core Data Proc Scenario Doc
11	Support MODIS Science Team Mtg
12	Prel MODIS Proc/Stor Req't Doc
13	Utility/Sup't Algo Req'ts Doc
14	MODIS SDST/ICT Requirem'ts Doc
15	Core Product Requirements Doc
16	
17	
18	
19	
20	



Note:

RAY TRACING CALCULATIONS OF ATMOSPHERIC REFRACTION EFFECTS ON MODIS PIXEL LOCATION

1. Introduction

A ray tracing calculation is performed to find the effects of atmospheric refraction on pixel location for MODIS. The ray tracing approach is the preferred method of tackling this problem. Simple geometric modelling of this problem will always lead to an overestimation of the refraction effects on pixel location. The ray tracing model shows that refraction effects are small compared to MODIS pixel sizes. The effect can be analytically calculated however and included in the MODIS data processing if needed.

2. Model atmosphere

The U. S. Standard Atmosphere 1976 was used for these calculations.

To calculate the index of refraction as a function of height, a model of temperature and pressure is required. The model for temperature is described in the following quote from the U. S. Standard Atmosphere, 1976: "Traditionally, standard atmospheres have defined temperature as a linear function of height to eliminate the need for numerical integration in the computation of pressure versus height. This standard follows the tradition to heights up to 86 km, and the function T versus H is expressed as a series of seven successive linear equations. The general form of these equations is

$$T = T_b + L_b * (H - H_b)$$

with the value of subscript b ranging from 0 to 6 in accordance with each of seven successive layers."

Values of T_b, L_b, and H_b are summarized in the following table, along with the corresponding atmospheric pressure in millibars:

b	H_b	L_b	T_b	P_b
0	0	-6.5	288.15	1013.25
1	11	0.0	216.74	226.32
2	20	1.0	216.74	54.748
3	32	2.8	228.65	8.8906
4	47	0.0	270.65	1.1090
5	51	-2.8	270.65	0.66938
6	71	-2.0	214.65	0.039564

For atmospheric pressure the following two equations apply, the first for L_b not equal to zero and the second for L_b equal to zero:

$$P = P_b \cdot \left[\frac{T_{M,b}}{T_{M,b} + L_{M,b} \cdot (H - H_b)} \right]^{\left[\frac{g_0' \cdot M_0}{R^* \cdot L_{M,b}} \right]}$$

and

$$P = P_b \cdot \exp \left[\frac{-g_0' \cdot M_0 \, (H - H_b)}{R^* \cdot T_{M,b}} \right].$$

The constant g equals 9.80665, R* equals 8314.32, and M_0 equals 28.9644. Values for P_b are tabulated in the table.

Based upon the above equations for temperature and pressure as a function of height, a model of temperature and pressure was calculated with a 1 kilometer resolution going from the surface to 72 kilometers. At 72 kilometers, the pressure is 0.04 mb, so virtually the entire atmosphere is included in the model. For temperature perturbations, a constant temperature was subtracted from each level. This approach will over-emphasize any temperature perturbations and so provide an upper limit on its effect. By varying the temperature plus and minus 20 degrees about the mean, 99% of the real variability of the atmosphere is included within the extremes. Figure 1 shows the temperature profile for the unperturbed model atmosphere. Figure 2 shows the corresponding pressure profile.

3. Ray tracing model

Given the temperature and pressure at each height, the atmospheres index of refraction can be calculated (see Figure 3). For a 0.7 micron wavelength, the index of refraction equals 1.0002907 at 15 degrees Celsius and 760 mm Hg. To convert the index of refraction to other temperatures and pressures, the model atmosphere temperatures are converted from Kelvin to Celsius by subtracting 273.15 and the pressure is converted from millibars to mm Hg by multiplying by 0.7500616. The following equation is then used:

$$(n_{t,p} - 1) = (n_{15,760} - 1) \frac{p[1 + (1.049 - 0.0157t) \times 10^{-6} p]}{720.883(1 + 0.003661\, t)}$$

where t is in °C and p in mmHg.

Using Snell's law, the ray path of a light beam can be traced through the atmosphere for any given incident angle. The path can be compared to a path of light for the case of no atmosphere and the perturbation in direction and distance can be found.

All the calculations are done for a spherical Earth with a radius of 6371 kilometers and with the satellite at a constant altitude of 705 kilometers. After the application of Snell's law to find the refraction angle, the angle that it will intersect

with the next shell one kilometer below is calculated. The refraction correction and Earth curvature correction are alternately applied every one kilometer until the Earth's surface is reached.

4. Refraction effects

Figure 4 shows the change in direction in degrees for a standard atmosphere and for an initial 45 degree nadir angle. The nadir angle is the angular difference between the nadir vector and the pointing vector, which is determined by scan and tilt angles. The perturbation in distance at any height will be proportional to this curve. As is evident, most of the light bending occurs low in the atmosphere. Since most of the refraction effects occur near the surface, the light will travel only a comparatively short distance in directions different from its initial top of the atmosphere direction. Consequently the refraction perturbation will be measured in meters.

The index of refraction varies slowly with wavelength. All the plots are for 0.7 microns. The difference in pixel location between 0.4 and 14.2 microns is about one tenth of the plotted values, so, for example, at a 55 degree nadir angle, the refraction corrections would differ by about 3 meters.

Figure 5 shows the refraction perturbation as a function of nadir angle from nadir (zero degrees) to 60 degrees for 5 different model atmospheres. Only for large nadir angles are differences of more than 10 meters occurring. The limb of the Earth is a 64.2 degrees for a satellite at 705 kilometers, at which point the error in pixel location approaches infinity. For nadir angles approaching 60 degrees, refraction effects may become quite important in determining pixel location.

5. Conclusion

Using a ray tracing program it is possible to calculate accurately the effects on pixel location. These effects are small, but may be significant for some applications. Since the effect can be analytically solved for, it is straight-forward to include the correction in the MODIS data processing.

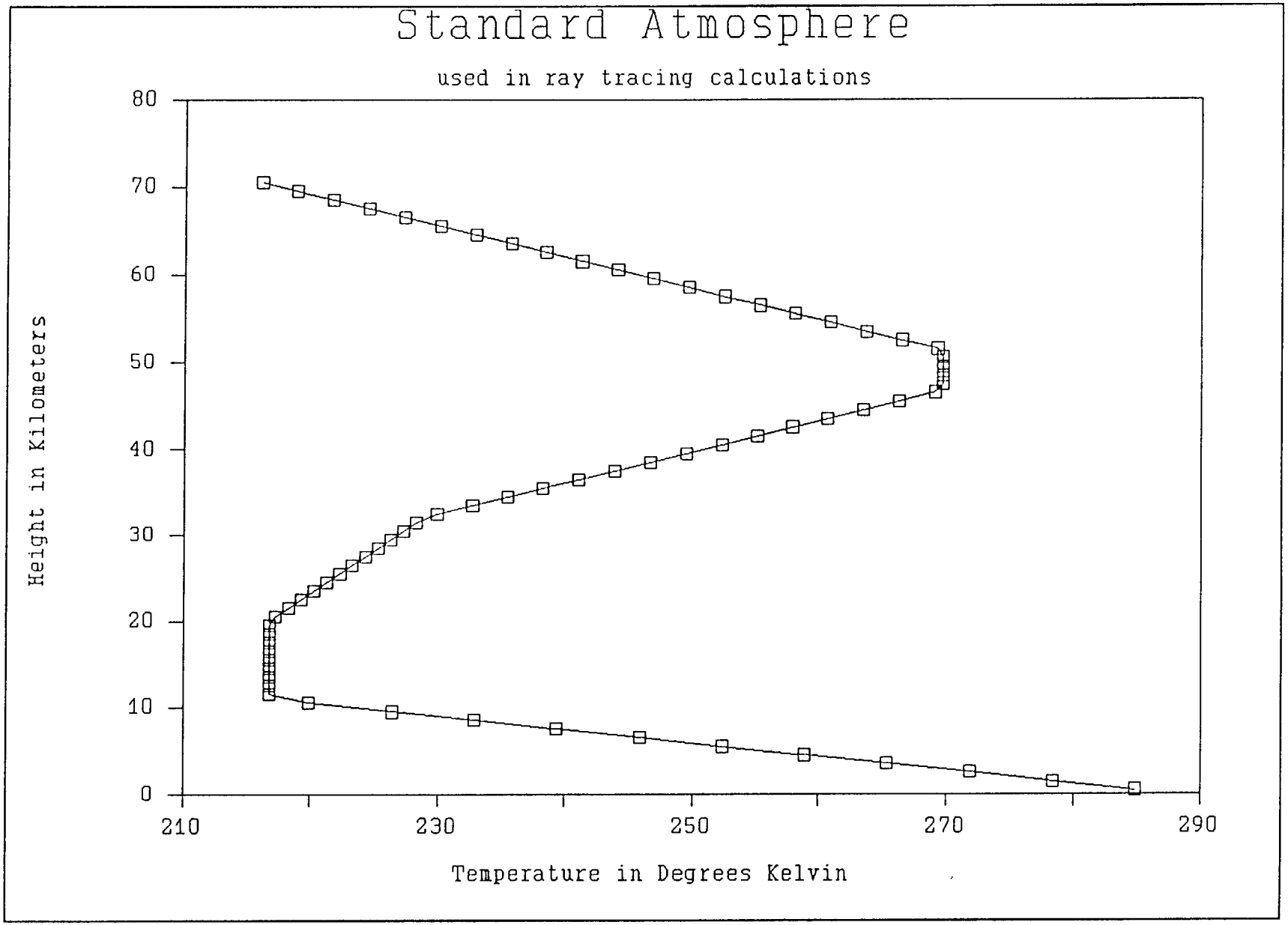

Standard Atmosphere
used in ray tracing calculations
Height in Kilometers
80
70
60
50
40
30
20
10
0
210
230
250
270
290
Temperature in Degrees Kelvin

Figure 1.

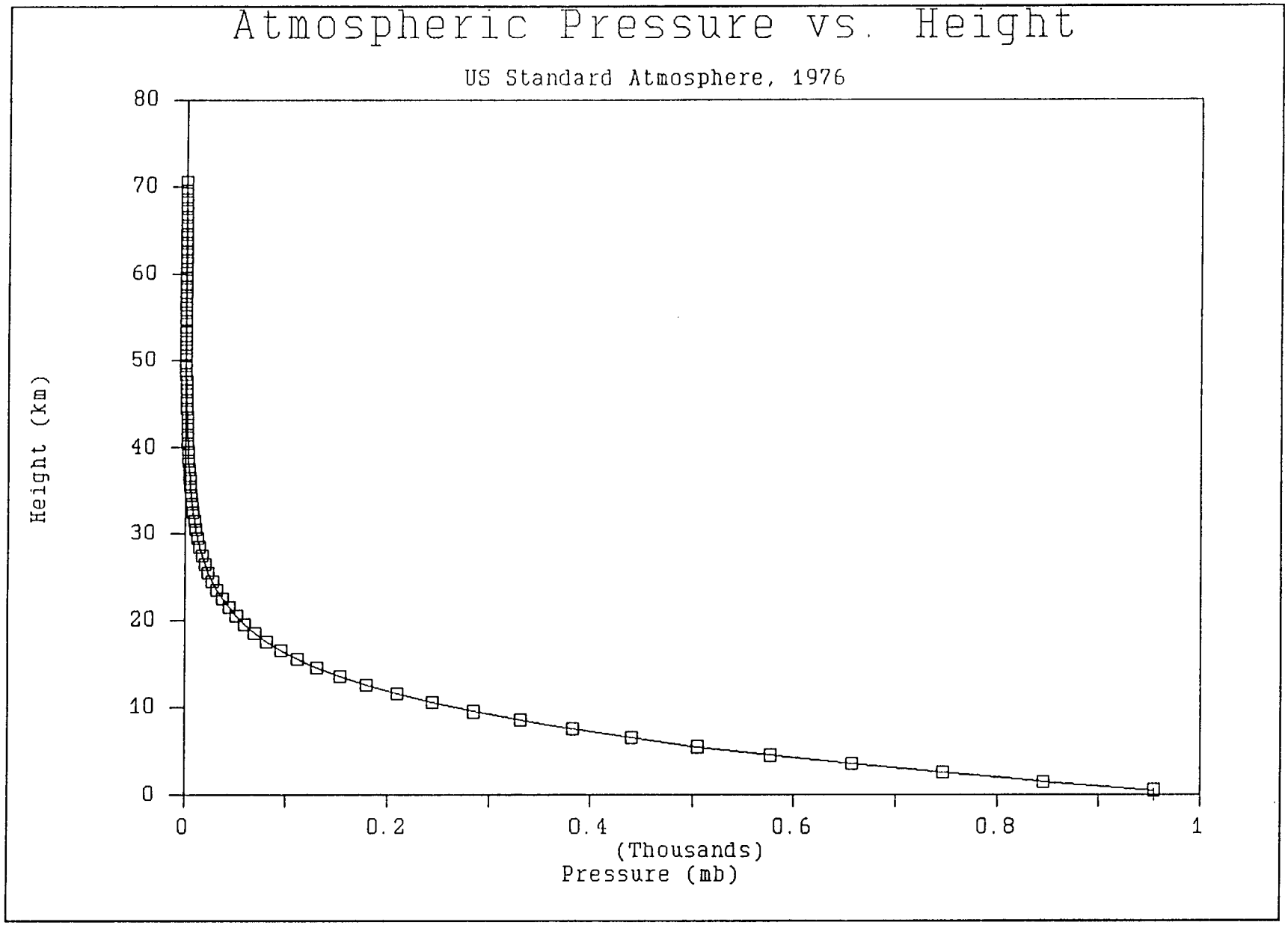

Atmospheric Pressure vs. Height
US Standard Atmosphere, 1976
Height (km)
80
70
60
50
40
30
20
10
0
0
0.2
0.4
0.6
0.8
1
(Thousands)
Pressure (mb)

Figure 2.

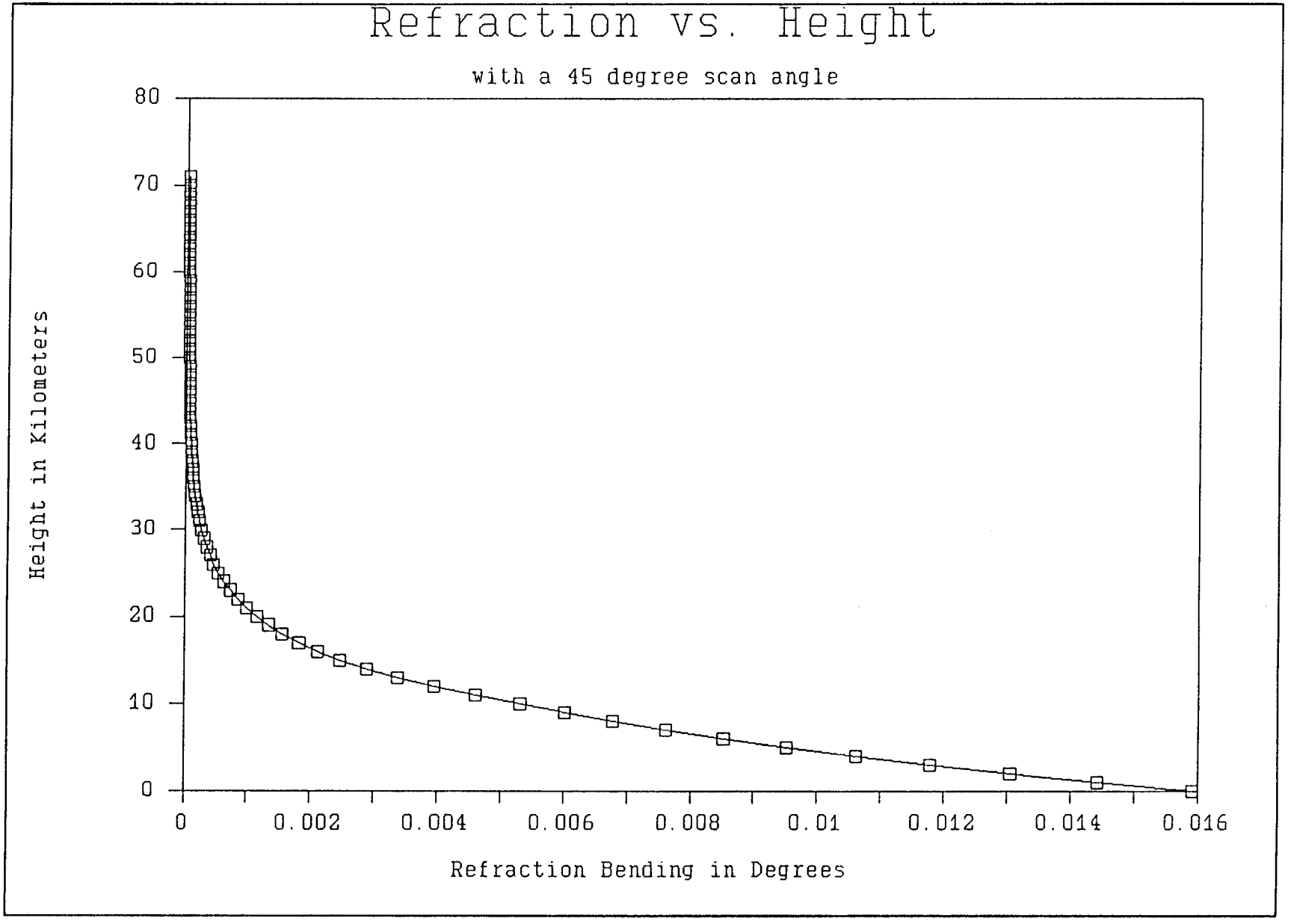

Refraction vs. Height
with a 45 degree scan angle
Height in Kilometers
80
70
60
50
40
30
20
10
0
0
0.002
0.004
0.006
0.008
0.01
0.012
0.014
0.016
Refraction Bending in Degrees

Figure 4.

USING THE RAY TRACING PROGRAM TO ESTIMATE OTHER ERRORS IN THE MODIS DATA PROCESSING

1. Introduction

The model described in the previous note can be applied to the analysis of related problems concerned with pixel location and with angles of incidence. Two applications of the model are illustrated below.

2. Pixel location and changes in satellite altitude

According to The Earth Observer (vol.1, no.3), the satellite's altitude above the Earth actually varies from 705 to 730 kilometers. This change in altitude can have substantial effects on pixel location. Figure 1 illustrates the altitude effect where the difference in pixel location for altitudes of 711, 717, 723, and 729 kilometers are calculated compared to the nominal 705 km altitude. The differences can be many tens of kilometers. At a 60 degree nadir angle, the change in pixel location is about 85 kilometers over one orbit, which has changes in satellite altitude of 25 kilometers. This implies that at this nadir angle, the location of a pixel to within 100 meters requires a knowledge of satellite altitude to within 28 meters.

3. Earth intersection angle and satellite altitude

As the satellite changes altitude during the course of an orbit, the angle at which a pixel is viewed also varies. Figure 2 shows the Earth intersection angles versus nadir angle for a satellite at 711 kilometers above the Earth. The intersection angle always exceeds the nadir angle because of the Earth's curvature. In Figure 3, the intersection angle is plotted for a typical nadir angle of 45 degrees and for satellite altitudes from 705 to 729 kilometers. The intersection angle is almost 52 degrees, but varies by about 0.25 degrees because of the changes of satellite altitude in any one orbit. Knowledge of the intersection angle can be important if a bi-directional reflectance model is being used. Over water, a small change in angle can lead to a large change in reflectance. At nadir angles approaching 60 degrees, the intersection angle can vary by as much as one half of a degree.

4. Conclusion

The model developed to study the effects of refraction on MODIS pixel location can be applied to other problems. Two such applications are given here. To keep pixel locations accurate to within 100 meters for all possible nadir angles, the satellite altitude must be known to within about 28 meters. To know the Earth intersection angle to within 0.01 degrees requires a knowledge of satellite altitude to within about 960 meters.

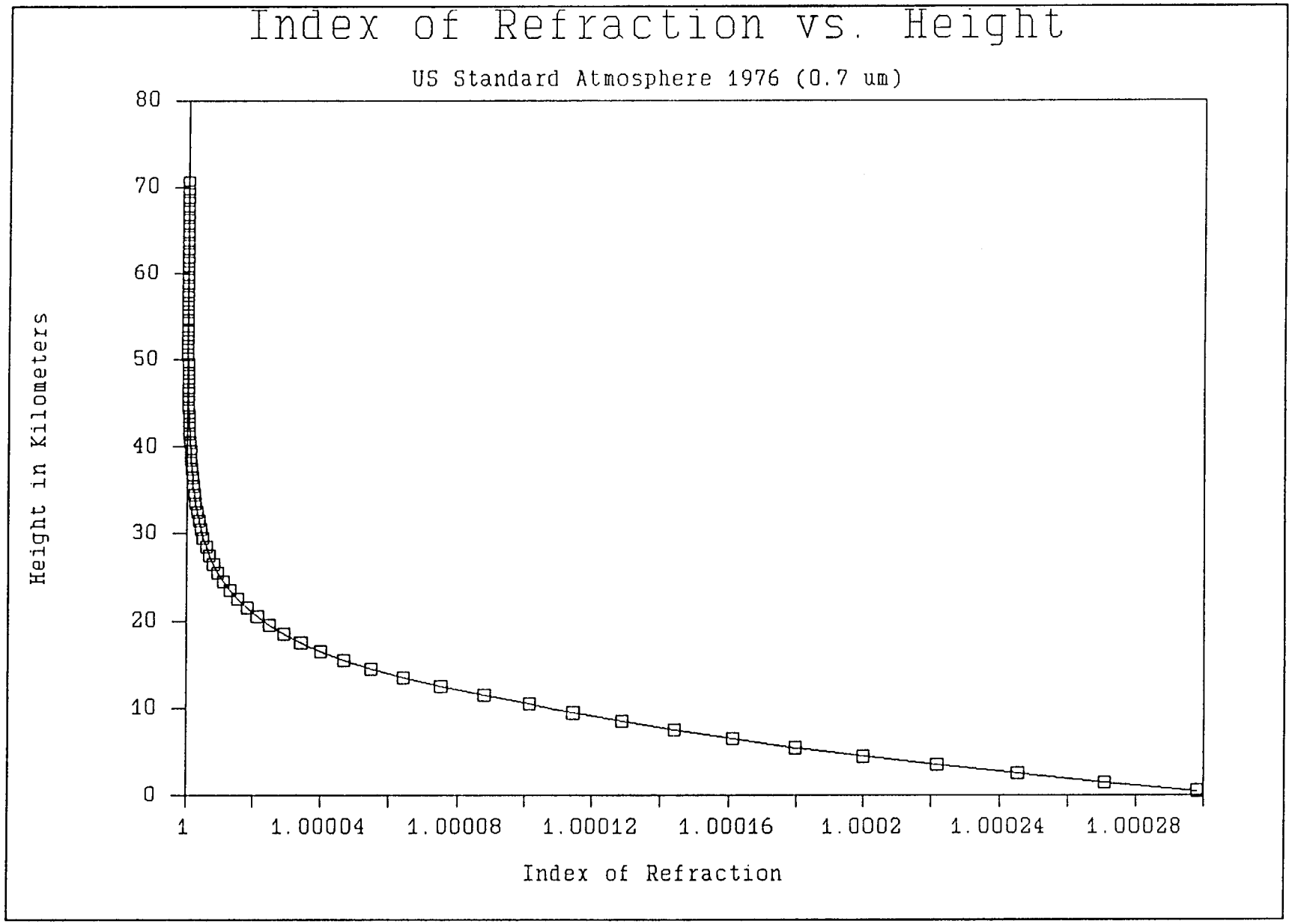

Index of Refraction vs. Height
US Standard Atmosphere 1976 (0.7 um)
Height in Kilometers
80
70
60
50
40
30
20
10
0
1
1.00004
1.00008
1.00012
1.00016
1.0002
1.00024
1.00028
Index of Refraction

Figure 3.

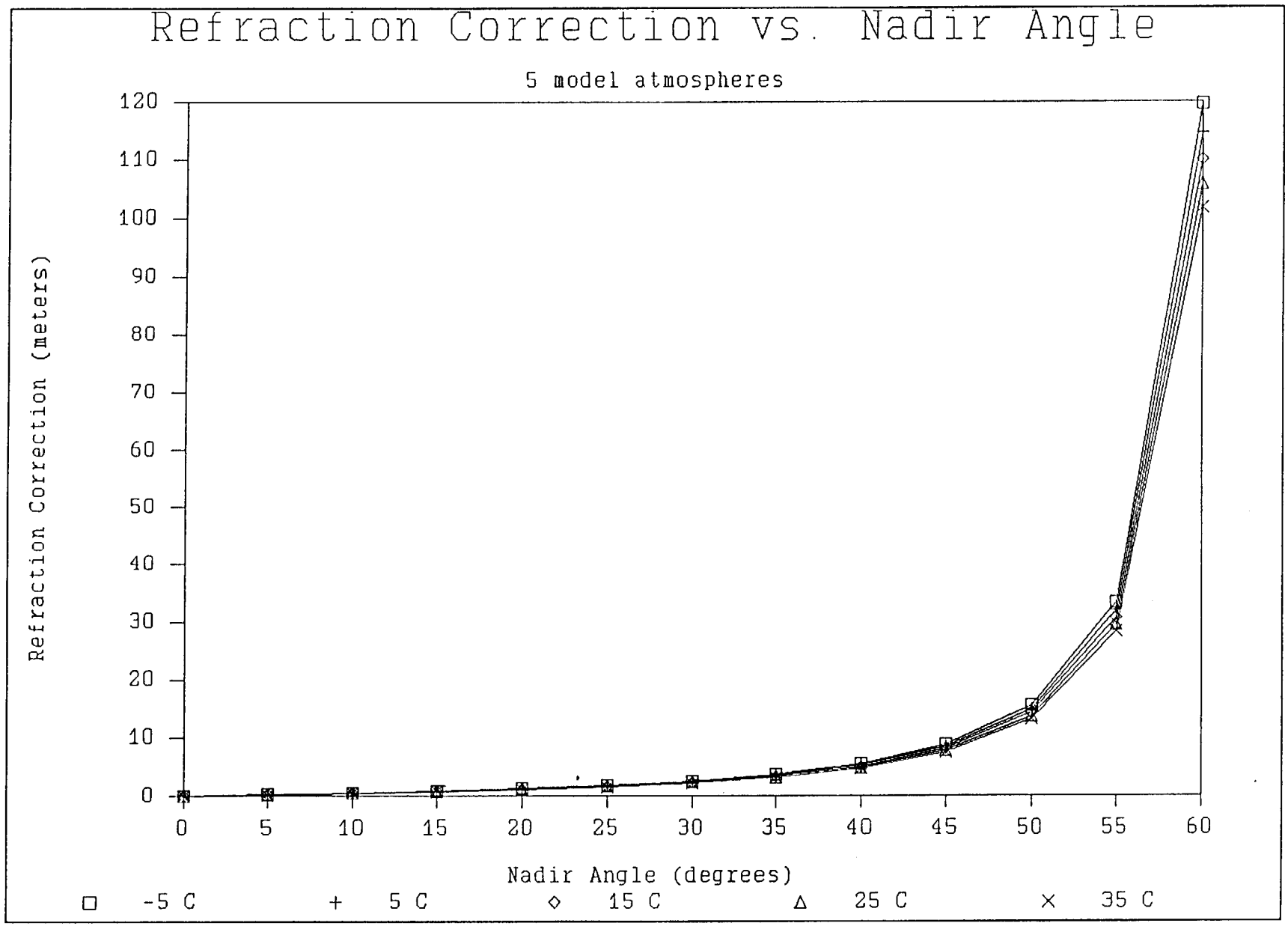

Refraction Correction vs. Nadir Angle
5 model atmospheres
Refraction Correction (meters)
120
110
100
90
80
70
60
50
40
30
20
10
0
0
5
10
15
20
25
30
35
40
45
50
55
60
Nadir Angle (degrees)
-5 C
5 C
15 C
25 C
35 C

Figure 5.

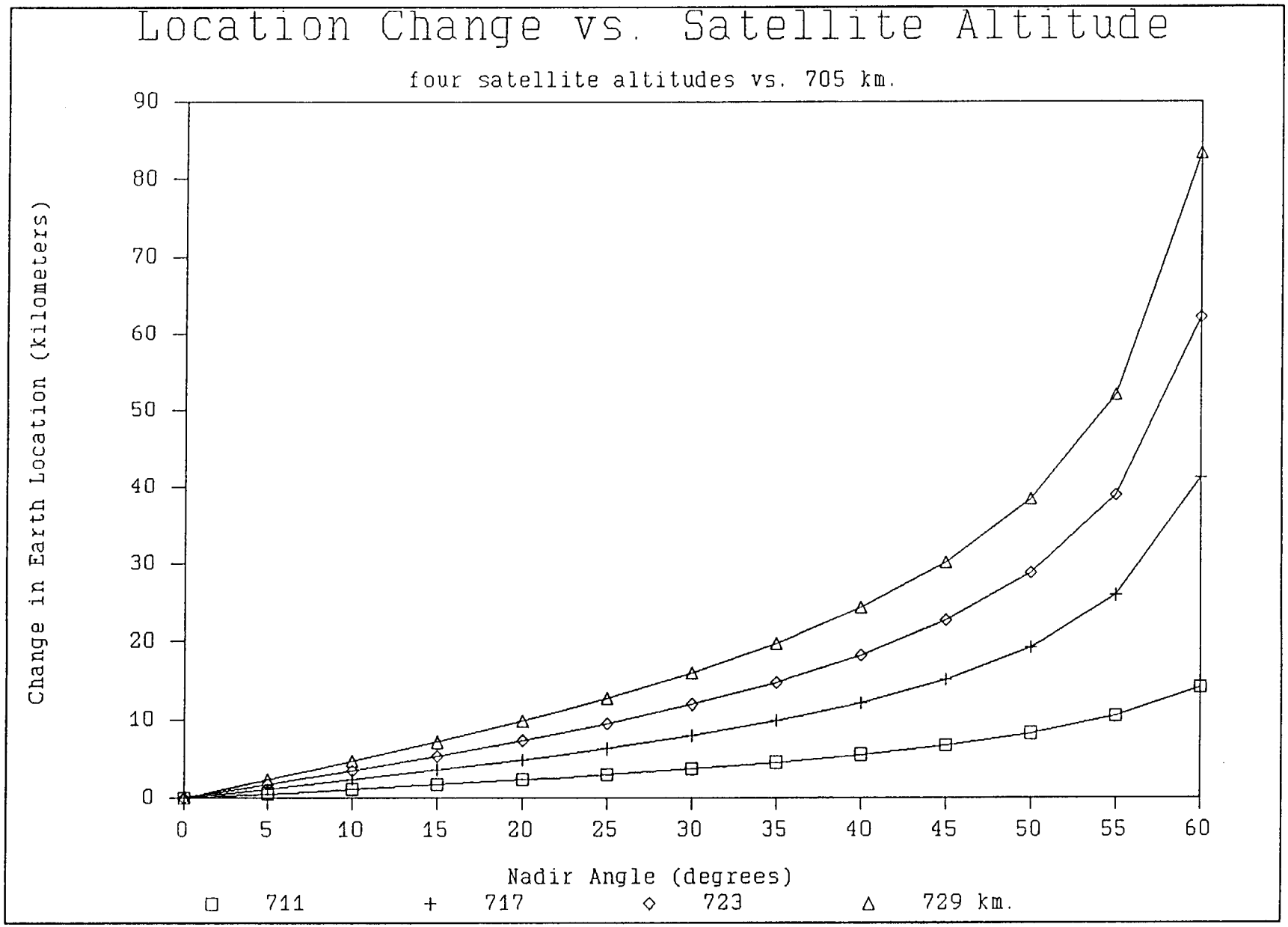

Location Change vs. Satellite Altitude
four satellite altitudes vs. 705 km.
Change in Earth Location (kilometers)
0
10
20
30
40
50
60
70
80
90
0
5
10
15
20
25
30
35
40
45
50
55
60
Nadir Angle (degrees)
711
717
723
729 km.

Figure 1.

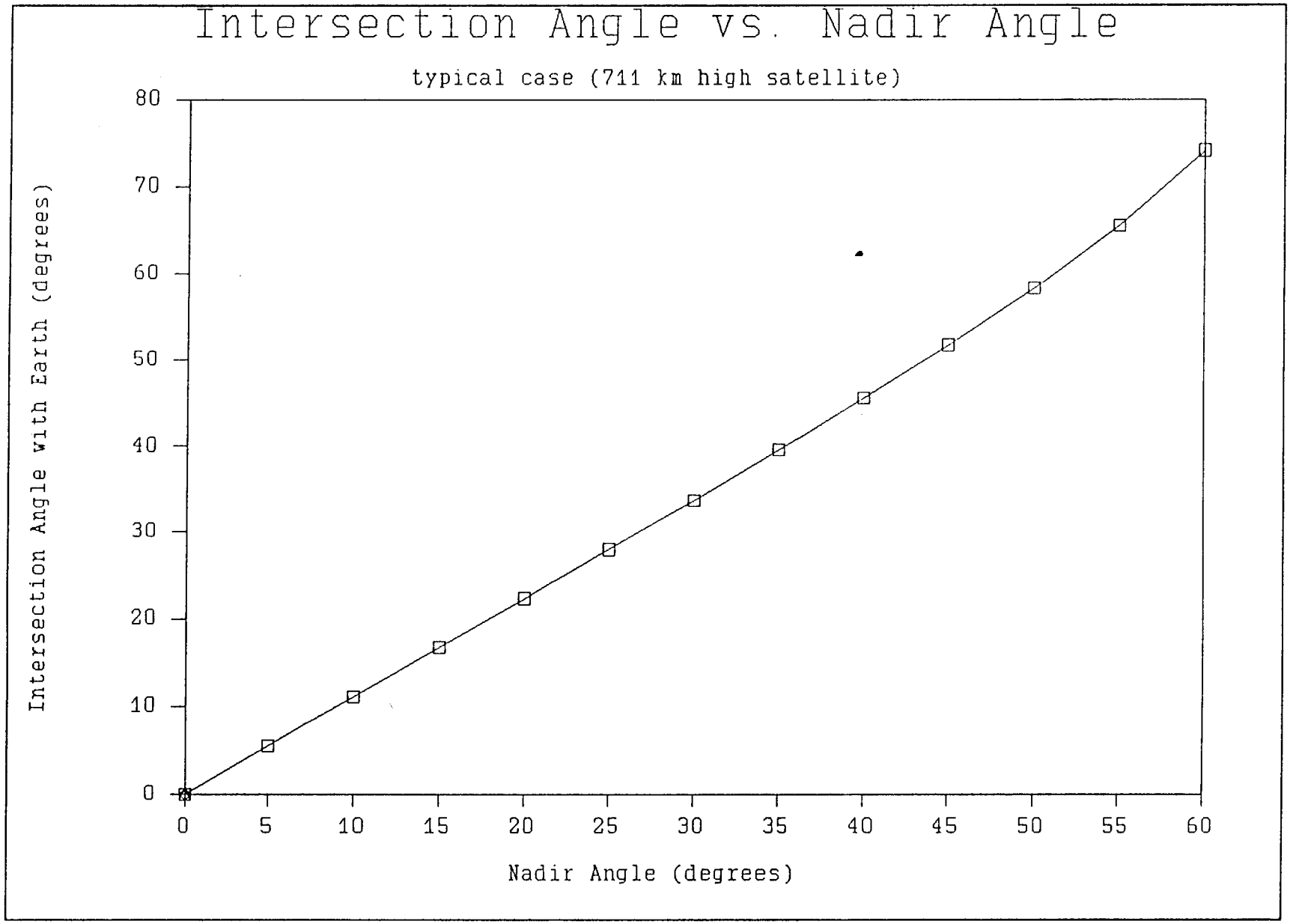

Intersection Angle vs. Nadir Angle
typical case (711 km high satellite)
Intersection Angle with Earth (degrees)
0
10
20
30
40
50
60
70
80
0
5
10
15
20
25
30
35
40
45
50
55
60
Nadir Angle (degrees)

Figure 2.

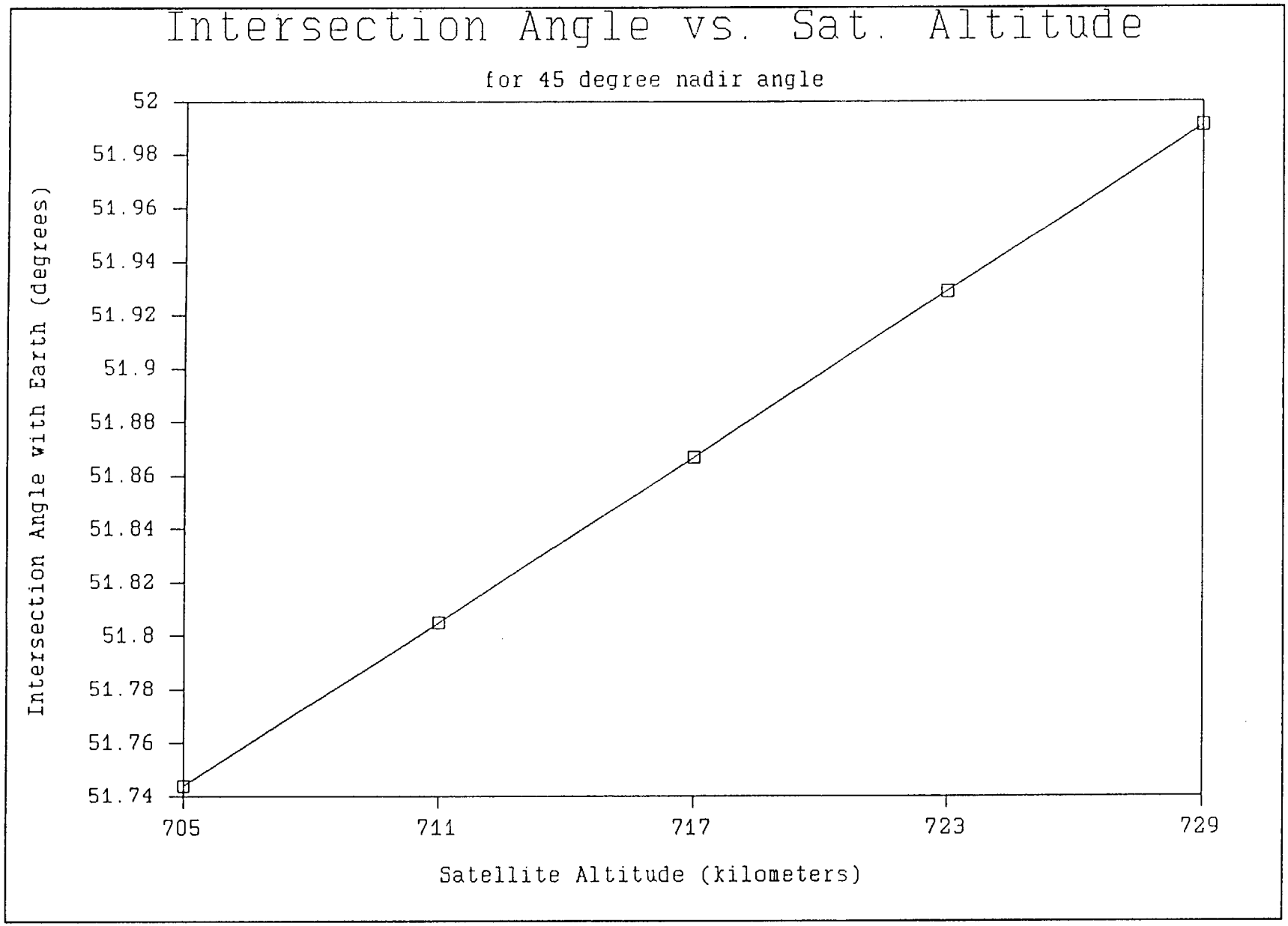

Intersection Angle vs. Sat. Altitude
for 45 degree nadir angle
Intersection Angle with Earth (degrees)
52
51.98
51.96
51.94
51.92
51.9
51.88
51.86
51.84
51.82
51.8
51.78
51.76
51.74
705
711
717
723
729
Satellite Altitude (kilometers)

Figure 3.

Notes from a Conversation with John Barker

The following notes are from a conversation with John Barker in which he presents his thoughts on new or revised EOS requirements being considered by the EOS Data Panel. These requirements are under discussion but have not been accepted. If accepted, they would impact current MODIS requirements.

Direct Downlink Requirement:

A direct downlink capability for science data is currently under discussion and may be provided in the X-band. Data would be processed to Level-1 or higher on-board the platform (within the instrument) and a real-time product would be distributed to users by direct downlink. Direct downlink products could serve as input for decisions involving forward looks by other instruments, field experiments, and ground processing to generate higher level products. Data quality would be automatically flagged to protect against data glitches or failures.

Quick-Look Requirement:

Assuming that a direct downlink exists, quick-look data would be processed on-board to a TBD level (and possibly at a lower spatial resolution) to provide data to anyone with the capability of receiving the direct downlink. Quick-look data might be a subset of science data, either selectable or 'hardwired', that would be routed through a real-time data link, either the direct downlink or TDRSS.

NDVI, Sea Surface Temperature, and Cloud Cover are examples of quick-look products.

An 'Instrument Characterization Team' (ICT) will need to have science data available in real-time to make decisions involving both the performance of the instrument and processing and/or field experiments. This task cannot be performed satisfactorily either at the ICC or the IST, which are geared toward engineering/health-and-safety monitoring and schedule conflict resolution, respectively.

Bypass of CDOS:

Direct downlink would provide access to data and data products much more quickly than the currently-envisioned CDOS and ground data system. It would also provide the team member with a larger percentage of quick turn-around data compared with the (20) percent Priority Playback or (10) percent Real-Time data available through CDOS. Foreign scientists would have efficient access to science data.

On-board processing:

The MODIS instrument will need a data buffering capability because of tape recorder requirements, and therefore an on-board processor will be required to accomplish the selecting, processing, and routing of science data. Selected data could be processed at a lower resolution to some agreed upon level on-board to provide a quick-look capability.

Browse Requirement:

Browse data may be used to make processing decisions, such as whether to do higher level processing for observations containing clouds at a given location. Browse data would be used to efficiently study small volumes of data or small areas, and would provide an alternative to the large volumes of data and large temporal/spatial areas that are efficiently handled in the currently envisioned data system. Browse data should allow a user to easily examine a specific area at high resolution, for a specific data product between two chosen dates, or to perform the same task at reduced spatial resolution. Browse data will be available from the DADS.

The types of browse data envisioned are:

Static browse.
Movie browse.

Static browse is defined as data which has been processed to a given level by the CDHF and extracted to a given time and area of interest, possibly at full resolution. Movie browse is defined as a data set at level-3 or higher which provides data throughout a requested time interval. Movie browse would need to be requested through the DADS in order to provide the data selection capability needed to retrieve data for the requested time interval. Browse data would be provided on a TBD medium or electronically (on-line).

Earth Radius (km)	6371		
Satellite Altitude (km)	705		
Orbital Period (min)	98.9		
MODIS-N # 856 m REF channels	15		
MODIS-N # 428 m REF channels	8		
MODIS-N # 214 m REF channels	2		
MODIS-N # 856 m TIR channels	15		
MODIS-T # 1 km REF channels	64		
MODIS-N # bits/REF channel	12		
MODIS-N # bits/TIR channel	12		
MODIS-T # bits/REF channel	12		
MODIS-N REF Duty Cycle	50%		
MODIS-N TIR Duty Cycle	100%		
MODIS-T REF Duty Cycle	50%		
MODIS-N # Along-track IFOVs	8		
MODIS-T # Along-track IFOVs	64		
MODIS-N # Along-track detectors	752		
MODIS-T # Along-track detectors	64		
MODIS-N Maximum scan angle (deg)	55		
MODIS-T Maximum scan angle (deg)	45		
MODIS-N IFOV FWHM (deg)	6.95E-02		
MODIS-T IFOV FWHM (deg)	8.13E-02		
MODIS-N # pixels along-scan/on-Earth	1582		
MODIS-T # pixels along-scan/on-Earth	1107		
MODIS-N Scan Period (sec)	1.02		
MODIS-T Scan Period (sec)	9.50		
MODIS-N VIS Data (megabits/scan)	12.0		
MODIS-N TIR Data (megabits/scan)	2.3		
MODIS-N Daytime Data (megabits/scan)	14.3		
MODIS-T Daytime Data (megabits/scan)	54.4		
MODIS-N # Scans/Orbit	5841	Contingency	
MODIS-T # Scans/Orbit	312	10%	Total
MODIS-N Daytime Data Rate (mbps)	14.1	1.4	15.5
MODIS-N Nighttime Data Rate (mbps)	2.2	0.2	2.5
MODIS-T Daytime Data Rate (mbps)	5.7	0.6	6.3
MODIS-N Orbital Ave Data Rate (mbps)	8.1	0.8	9.0
MODIS-T Orbital Ave Data Rate (mbps)	2.9	0.3	3.2
MODIS-N Daily Data Volume (gigabits)	703.9	70.4	774.2
MODIS-T Daily Data Volume (gigabits)	247.6	24.8	272.4
Total MODIS Data Volume (gigabits)	951.5	95.1	1046.6

Table 1a. MODIS-N and MODIS-T Data Rate and Volume Estimates, baseline parameters.

Earth Radius (km)	6371		
Satellite Altitude (km)	705		
Orbital Period (min)	98.9		
MODIS-N # 856 m REF channels	15		
MODIS-N # 428 m REF channels	8		
MODIS-N # 214 m REF channels	2		
MODIS-N # 856 m TIR channels	15		
MODIS-T # 1 km REF channels	32		
MODIS-N # bits/REF channel	12		
MODIS-N # bits/TIR channel	12		
MODIS-T # bits/REF channel	12		
MODIS-N REF Duty Cycle	50%		
MODIS-N TIR Duty Cycle	100%		
MODIS-T REF Duty Cycle	50%		
MODIS-N # Along-track IFOVs	8		
MODIS-T # Along-track IFOVs	64		
MODIS-N # Along-track detectors	752		
MODIS-T # Along-track detectors	64		
MODIS-N Maximum scan angle (deg)	55		
MODIS-T Maximum scan angle (deg)	45		
MODIS-N IFOV FWHM (deg)	6.95E-02		
MODIS-T IFOV FWHM (deg)	8.13E-02		
MODIS-N # pixels along-scan/on-Earth	1582		
MODIS-T # pixels along-scan/on-Earth	1107		
MODIS-N Scan Period (sec)	1.02		
MODIS-T Scan Period (sec)	9.50		
MODIS-N VIS Data (megabits/scan)	12.0		
MODIS-N TIR Data (megabits/scan)	2.3		
MODIS-N Daytime Data (megabits/scan)	14.3		
MODIS-T Daytime Data (megabits/scan)	27.2		
MODIS-N # Scans/Orbit	5841		Contingency
MODIS-T # Scans/Orbit	312	10%	Total
MODIS-N Daytime Data Rate (mbps)	14.1	1.4	15.5
MODIS-N Nighttime Data Rate (mbps)	2.2	0.2	2.5
MODIS-T Daytime Data Rate (mbps)	2.9	0.3	3.2
MODIS-N Orbital Ave Data Rate (mbps)	8.1	0.8	9.0
MODIS-T Orbital Ave Data Rate (mbps)	1.4	0.1	1.6
MODIS-N Daily Data Volume (gigabits)	703.9	70.4	774.2
MODIS-T Daily Data Volume (gigabits)	123.8	12.4	136.2
Total MODIS Data Volume (gigabits)	827.7	82.8	910.4

Table 1b. MODIS-N and MODIS-T Data Rate and Volume Estimates, baseline parameters, except MODIS-T with 32 channels.

Earth Radius (km)	6371		
Satellite Altitude (km)	705		
Orbital Period (min)	98.9		
MODIS-N # 856 m REF channels	15		
MODIS-N # 428 m REF channels	8		
MODIS-N # 214 m REF channels	2		
MODIS-N # 856 m TIR channels	15		
MODIS-T # 1 km REF channels	64		
MODIS-N # bits/REF channel	12		
MODIS-N # bits/TIR channel	12		
MODIS-T # bits/REF channel	14		
MODIS-N REF Duty Cycle	50%		
MODIS-N TIR Duty Cycle	100%		
MODIS-T REF Duty Cycle	50%		
MODIS-N # Along-track IFOVs	8		
MODIS-T # Along-track IFOVs	64		
MODIS-N # Along-track detectors	752		
MODIS-T # Along-track detectors	64		
MODIS-N Maximum scan angle (deg)	55		
MODIS-T Maximum scan angle (deg)	45		
MODIS-N IFOV FWHM (deg)	6.95E-02		
MODIS-T IFOV FWHM (deg)	8.13E-02		
MODIS-N # pixels along-scan/on-Earth	1582		
MODIS-T # pixels along-scan/on-Earth	1107		
MODIS-N Scan Period (sec)	1.02		
MODIS-T Scan Period (sec)	9.50		
MODIS-N VIS Data (megabits/scan)	12.0		
MODIS-N TIR Data (megabits/scan)	2.3		
MODIS-N Daytime Data (megabits/scan)	14.3		
MODIS-T Daytime Data (megabits/scan)	63.5		
MODIS-N # Scans/Orbit	5841		
MODIS-T # Scans/Orbit	312		
		Contingency 10%	Total
MODIS-N Daytime Data Rate (mbps)	14.1	1.4	15.5
MODIS-N Nighttime Data Rate (mbps)	2.2	0.2	2.5
MODIS-T Daytime Data Rate (mbps)	6.7	0.7	7.4
MODIS-N Orbital Ave Data Rate (mbps)	8.1	0.8	9.0
MODIS-T Orbital Ave Data Rate (mbps)	3.3	0.3	3.7
MODIS-N Daily Data Volume (gigabits)	703.9	70.4	774.2
MODIS-T Daily Data Volume (gigabits)	288.9	28.9	317.8
Total MODIS Data Volume (gigabits)	992.8	99.3	1092.0

Table 1c. MODIS-N and MODIS-T Data Rate and Volume Estimates, baseline parameters, except MODIS-T with 14 bits.