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LANDSAT DATA CONTINUITY MISSION

LANDSAT WORLDWIDE REFERENCE SYSTEM-2 (WRS-2) DEFINITION

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Goddard Space Flight Center
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CM FOREWORD

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1.0 Purpose

The Landsat Worldwide Reference System-2 (WRS-2) provides an indexing scheme for the repeating pattern of orbital ground tracks traversed by the Landsat 4, 5, and 7 spacecraft over their 16-day orbital repeat cycle. The original WRS (WRS-1) was designed for the Landsat 1, 2, and 3 missions which flew in a higher orbit. The current WRS-2 was designed for the 705-km orbit used by the later missions.

1.1 WRS-2 Scene Definition

Although the Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+) imagers collect continuous along-track swaths of data while operating, the data are cataloged and distributed as fixed-size along-track image segments referred to as scenes. Standard Landsat scenes are extracted around nominal scene-center coordinates and are sized so as to provide along-track overlap between adjacent scenes. Figure 1 shows how a continuous Landsat swath is segmented into overlapping scenes, based on the WRS grid, for cataloging and distribution. Although the standard scene size is often cited as 185-km cross-track (based upon the TM/ETM+ field of view) by 170-km along-track, the Landsat 7 scenes distributed by the USGS Center for EROS contain 375 ETM+ scans, each nominally covering 0.48 km, so a full scene actually spans approximately 180 km. Based upon this heritage, a LDCM scene area is defined as 185-km cross-track by 180-km along-track.

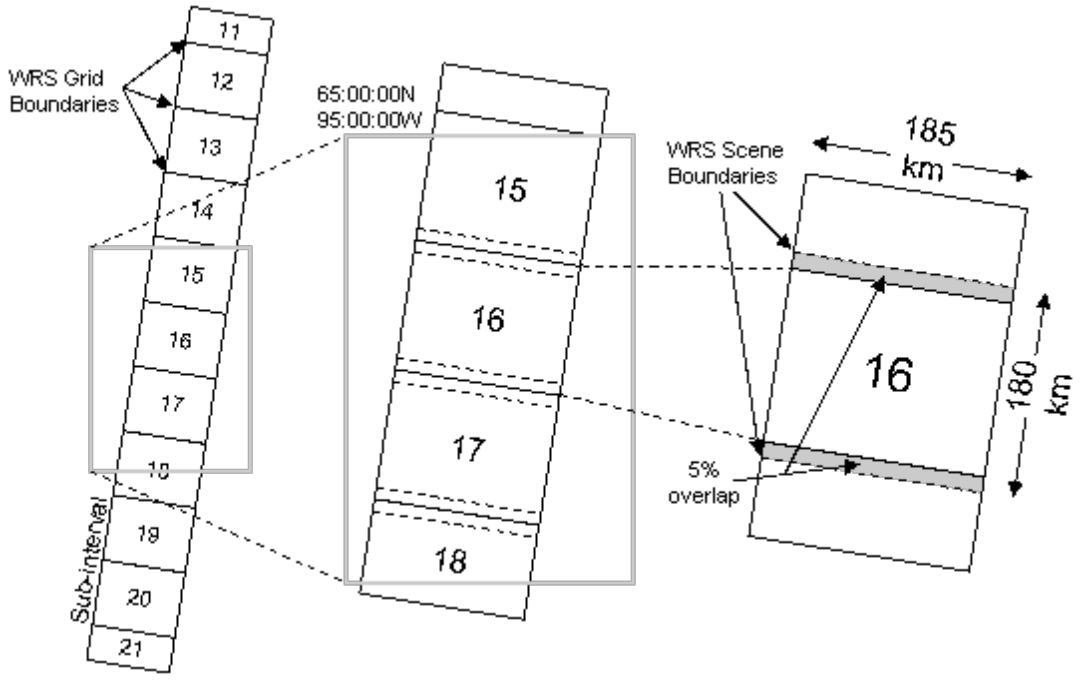

Figure 1: A continuous image swath is logically subdivided into overlapping scenes.

1.2 WRS-2 Path Definition

The WRS indexes orbits (paths) and scene centers (rows) into a global grid system comprising 233 paths by 248 rows. Since adjacent Landsat scenes overlap, indexing the location of an acquisition by latitude/longitude can be ambiguous and, in any event, provides little insight into where the scene falls in the 16-day acquisition cycle. The path/row notation provides a standard designator for every nominal scene center that can be readily related to both the 16-day acquisition cycle and longitude and latitude coordinates. Once established for Landsat-4, the WRS-2 also provided the target data collection pattern for subsequent missions, ensuring that Earth targets were observed using common viewing geometry, independent of the collecting spacecraft.

The Landsat orbital altitude and repeat cycle dictate that the 16-day acquisition cycle is completed in 233 orbits. The repeating ground tracks corresponding to the 233 orbits that make up a complete acquisition cycle are numbered sequentially with the numbers increasing to the west. The number of unique ground tracks means that *adjacent ground tracks* are approximately 172 km apart at the equator. The Earth's rotation during each revolution of the spacecraft in its sun-synchronous orbit causes *consecutive orbits* to be approximately 2752 km apart at the equator. Thus, each orbit advances 16 paths (2752/172), causing each WRS path to be traversed once per 16-day cycle in an interleaved pattern. Figure 2 shows the time sequence of WRS paths over a 16-day acquisition cycle.

Cycle Day	Paths														
1	1	17	33	49	65	81	97	113	129	145	161	177	193	209	225
2	8	24	40	56	72	88	104	120	136	152	168	184	200	216	232
3	15	31	47	63	79	95	111	127	143	159	175	191	207	223	
4	6	22	38	54	70	86	102	118	134	150	166	182	198	214	230
5	13	29	45	61	77	93	109	125	141	157	173	189	205	221	
6	4	20	36	52	68	84	100	116	132	148	164	180	196	212	228
7	11	27	43	59	75	91	107	123	139	155	171	187	203	219	
8	2	18	34	50	66	82	98	114	130	146	162	178	194	210	226
9	9	25	41	57	73	89	105	121	137	153	169	185	201	217	233
10	16	32	48	64	80	96	112	128	144	160	176	192	208	224	
11	7	23	39	55	71	87	103	119	135	151	167	183	199	215	231
12	14	30	46	62	78	94	110	126	142	158	174	190	206	222	
13	5	21	37	53	69	85	101	117	133	149	165	181	197	213	229
14	12	28	44	60	76	92	108	124	140	156	172	188	204	220	
15	3	19	35	51	67	83	99	115	131	147	163	179	195	211	227
16	10	26	42	58	74	90	106	122	138	154	170	186	202	218	

Figure 2: WRS-2 path time sequence.

1.3 WRS-2 Row Definition

Segmenting each Landsat orbit into 248 equally spaced scenes, covering both the day and night sides of the Earth, leads to a set of scene centers separated by just under 162 km. Thus, approximately 10% of the 180 km scene coverage overlaps the adjacent scenes.

The WRS row system is indexed so that the scene center at the orbital descending node is row 60, with the row numbers increasing in the along-track direction. Note that unlike the path numbers which, being fixed to the orbital ground tracks, must be integers, fractional row numbers are possible by shifting the scene window along-track relative to the fixed WRS-2 scene centers.

2.0 Mathematical Definition of the WRS-2 Grid

The WRS-2 grid is related to WGS84 geodetic latitude/longitude coordinates using the nominal Landsat orbital parameters. The procedure for computing the WRS scene center is described below. Figure 3 shows the input parameters used in the subsequent WRS scene center computations.

Parameter	**Value**
Earth Parameters	
Semi-Major Axis (WGS84)	6378137.0 m
Semi-Minor Axis (WGS84)	6356752.314 m
Orbit Parameters	
Inclination	98.2 degrees
WRS Parameters	
Number of Paths	233
Number of Rows	248
WRS Repeat Cycle	16 days
Descending Node Row	60
Longitude of Path 001, Row 060	-64.6 degrees (64.6 West)
Scene Parameters	
Path	Integer 1-233
Row	Float $0.5 < R < 248.5$

Figure 3: WRS-2 input parameters.

The unknown values to be computed are:
WRS Scene Center Latitude (WRS_Lat)
WRS Scene Center Longitude (WRS_Long)

2.1 WRS-2 Nominal Scene Center Computation Algorithm

Convert input angles to radians:

$$\text{Inclination\_Angle} = \pi / 180 * \text{Inclination\_Angle}$$
$$\text{Long\_Path1\_Row60} = \pi / 180 * \text{Long\_Path1\_Row60}$$

Compute the Earth's angular rotation rate:

$$\text{earth\_spin\_rate} = 2\pi / (24 * 3600)$$

Note: This computation uses the solar rotation rate, rather than the sidereal rate as called for in the General Electric Landsat D Program Information Release (PIR) that first described the Worldwide Reference System-2, in order to account for the orbital precession which is designed to make the orbit sun synchronous. Thus, the apparent Earth angular velocity is the inertial (sidereal) angular velocity plus the mean precession rate which, by design, is equal to the solar angular rate.

Compute the spacecraft's angular rotation rate:

SC_Ang_Rate = 2 π * WRS_Cycle_Orbits / (WRS_Cycle_Days * 24 * 3600)

Compute the central travel angle from the descending node:

Central_Angle = (Row - Descending_Node_Row)/Scenes_Per_Orbit * 2 π

Compute the WRS geocentric latitude:

WRS_GCLat = asin(-sin(Central_Angle) * sin(Inclination_Angle))

Compute the longitude of Row 60 for this Path:

Long_Origin = Long_Path1_Row60 - (Path - 1) * 2 π / WRS_Cycle_Orbits

Compute the WRS longitude:

Delta_Long = atan2(tan(WRS_GCLat)/tan(Inclination_Angle),
cos(Central_Angle)/cos(WRS_GCLat))

WRS_Long = Long_Origin - Delta_Long - Central_Angle * Earth_Spin_Rate / SC_Ang_Rate

Make sure the longitude is in the range +/-π:

While (WRS_Long > π)
WRS_Long = WRS_Long - 2 π
While (WRS_Long < - π)
WRS_Long = WRS_Long + 2 π

Convert the WRS geocentric latitude to geodetic latitude:

WRS_Lat = atan(tan(WRS_GCLat) * (Semi_Major_Axis/Semi_Minor_Axis)
* (Semi_Major_Axis/Semi_Minor_Axis))

Convert angles to degrees:

WRS_Lat = WRS_Lat * 180 / π
WRS_Long = WRS_Long * 180 / π

Round WRS lat/long off to the nearest whole arc minute:

WRS_Lat = round(WRS_Lat*60) / 60

WRS_Long = round(WRS_Long*60) / 60

Return the results:
WRS_Lat
WRS_Long

3.0 References

Landsat 7 Science Data Users Handbook, prepared by Landsat Project Science Office, *http://ltpwww.gsfc.nasa.gov/IAS/handbook/handbook_toc.html*, last updated 10 May 2005.

Landsat 7 Image Assessment System Geometric Algorithm Theoretical Basis Document, Version 3.2, prepared by Landsat Project Office, *http://ltpwww.gsfc.nasa.gov/IAS/handbook/pdfs/L7_geometry_ATBD.pdf*, last updated 09 July 1998.

Landsat 7 System Program Coordinates System Standard, Revision B, prepared by Martin Marietta Astro Space, document number PS23007610B, dated 2 December 1994.

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