Library

Subject: Interpolation Error for MODIS Ideal Filter Transmission Data
Author: Dan Knowles Jr.
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Since MODIS ideal filter transmission data is frequently received at a lower resolution than desired, a necessity arose for interpolating this data to a higher resolution. This paper depicts a brief study of the error introduced through a linear interpolation of this data.

Using SBRC formulas, ideal filter data was generated at several resolutions for several bands. This data was analyzed from -2 bandwidths to +2 bandwidths, covering the majority of the transmission signal. A linear interpolation was performed on this data resulting in a data set at a higher resolution. This higher resolution interpolated data set was then compared higher resolution data generated from SBRC formulas. The residual error, *E(Band,i,Bw)*, obtained from this comparison, was calculated as follows:

$$E(Band,i,Bw) = 100 \cdot \frac{t_i - t_s}{t_s}$$

where:

t_i = *interpolated transmission*
t_s = *transmission generated by SBRC formulas*
Band = *MODIS Band number*
i = *resolution (interval) of the data prior to interpolation*
Bw = *bandwidth*

The total residual error for the analyzed wavelength range was determined as follows:

$$E_T(Band,i) = \int_{-2Bw}^{+2Bw} E(Band,i,Bw) \bullet dBw$$

Several bands were interpolated with the following results:

E_T(*Band 1, 2nm*) = *20.1%*
E_T(*Band 1, 1nm*) = *4.9%*
E_T(*Band 1, .5nm*) = *1.2%*
E_T(*Band 4, 1nm*) = *7.1%*
E_T(*Band 8, 1nm*) = *12.7%*
E_T(*Band 9, 1nm*) = *12.2%*
E_T(*Band 18, 1nm*) = *3.4%*
E_T(*Band 32, 10nm*) = *1.5%*
E_T(*Band 36, 10nm*) = *1.2%*

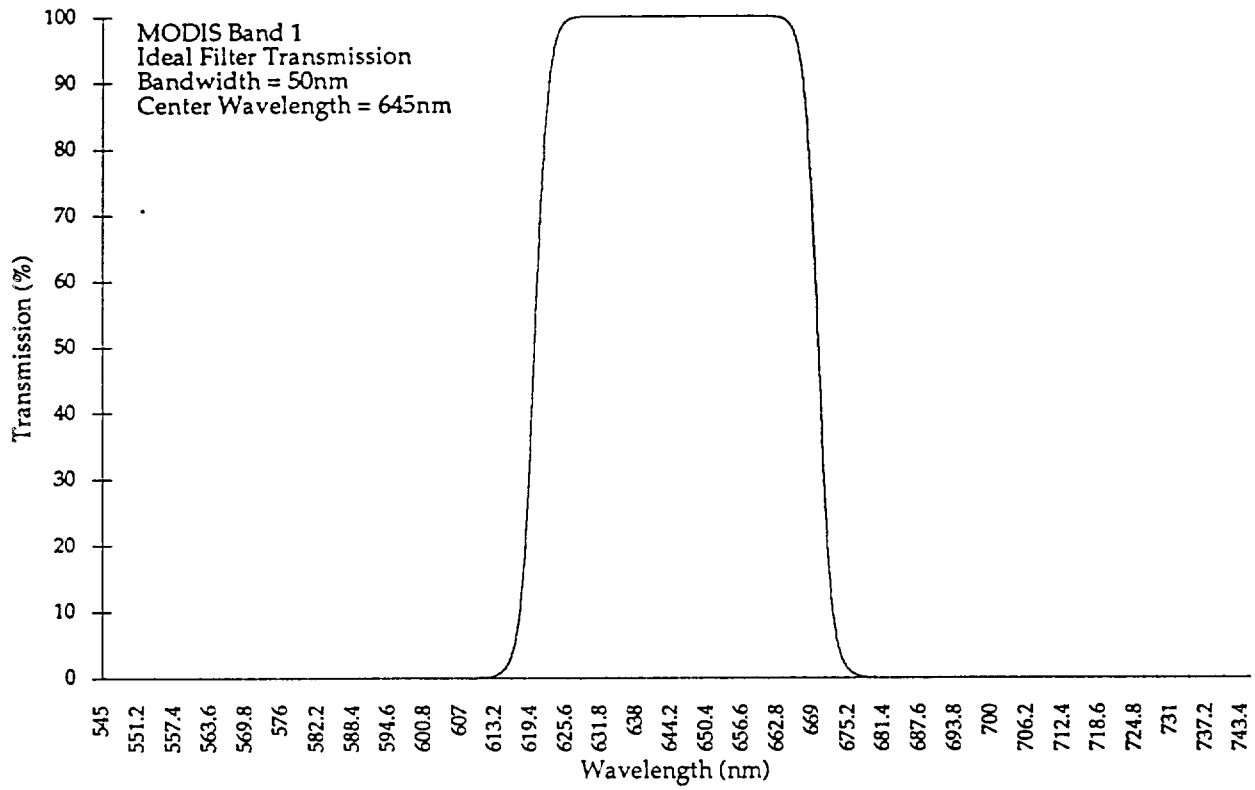
The peak residual errors, $E_{Peak}(Band, i, Bw)$, for each of these cases are:

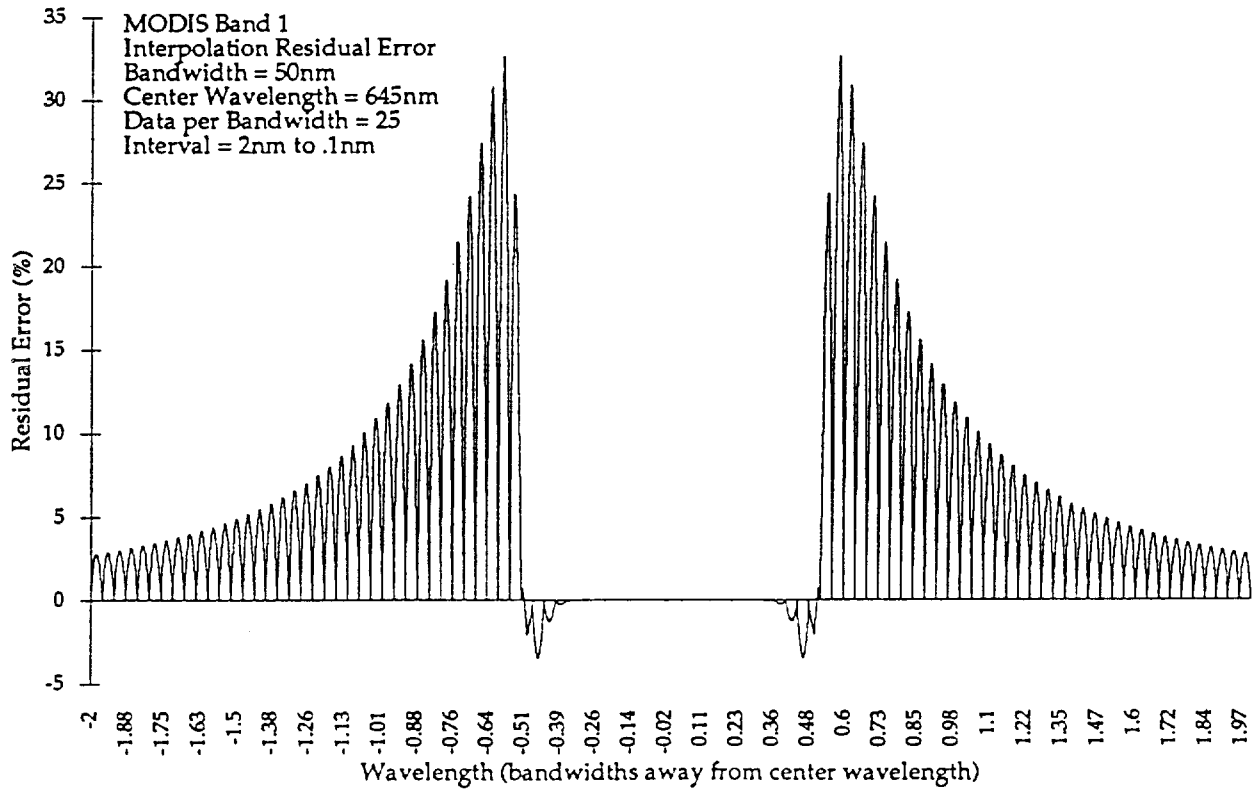
$E_{Peak}(Band\ 1, 2nm, \pm.58Bw) = 32.6\%$
$E_{Peak}(Band\ 1, 1nm, \pm.59Bw) = 7.4\%$
$E_{Peak}(Band\ 1, .5nm, \pm.58Bw) = 1.8\%$
$E_{Peak}(Band\ 4, 1nm, \pm.63Bw) = 9.2\%$
$E_{Peak}(Band\ 8, 1nm, \pm.54Bw) = 17.4\%$
$E_{Peak}(Band\ 9, 1nm, \pm.66Bw) = 14.0\%$
$E_{Peak}(Band\ 18, 1nm, \pm.75Bw) = 3.2\%$
$E_{Peak}(Band\ 32, 10nm, \pm.63Bw) = 2.0\%$
$E_{Peak}(Band\ 36, 10nm, \pm.68Bw) = 1.3\%$

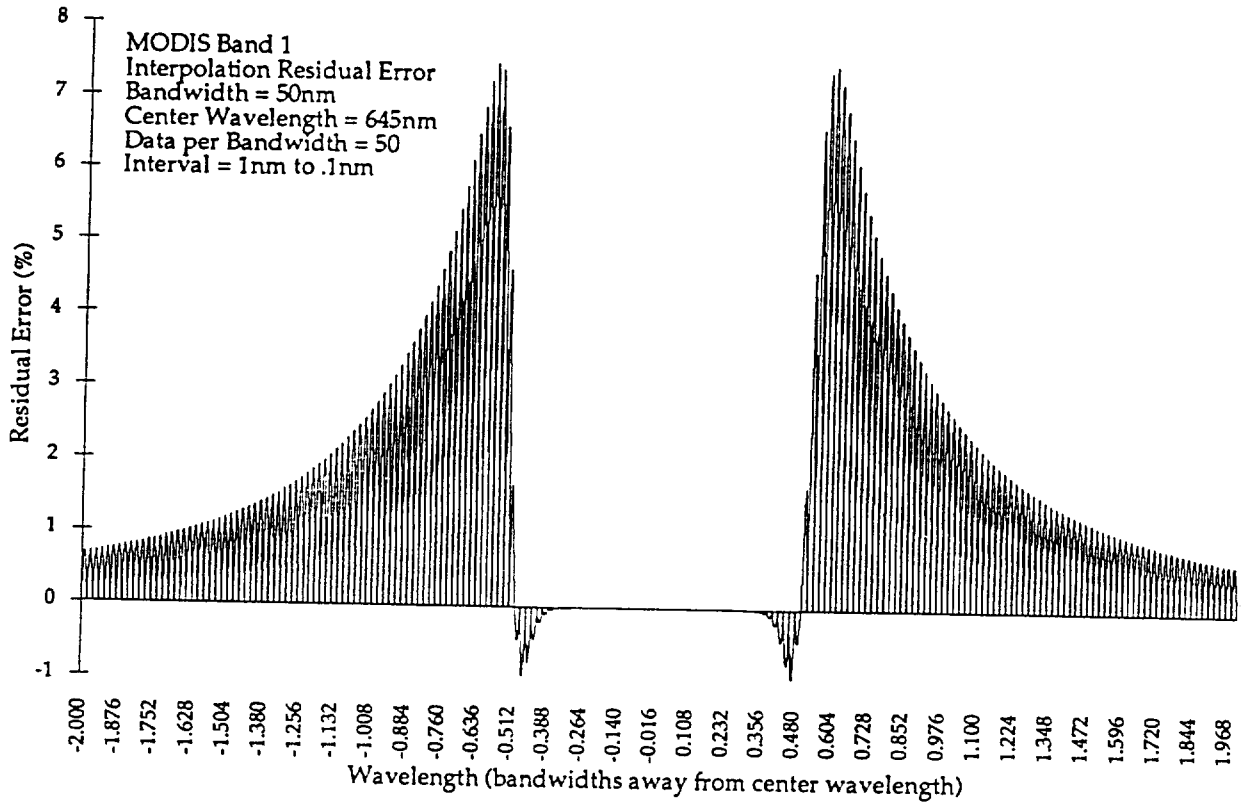
For each of the MODIS bands, the ratio, Bw/i., the number of data points per bandwidth, has a direct correlation with E_T. This can be demonstrated as follows:

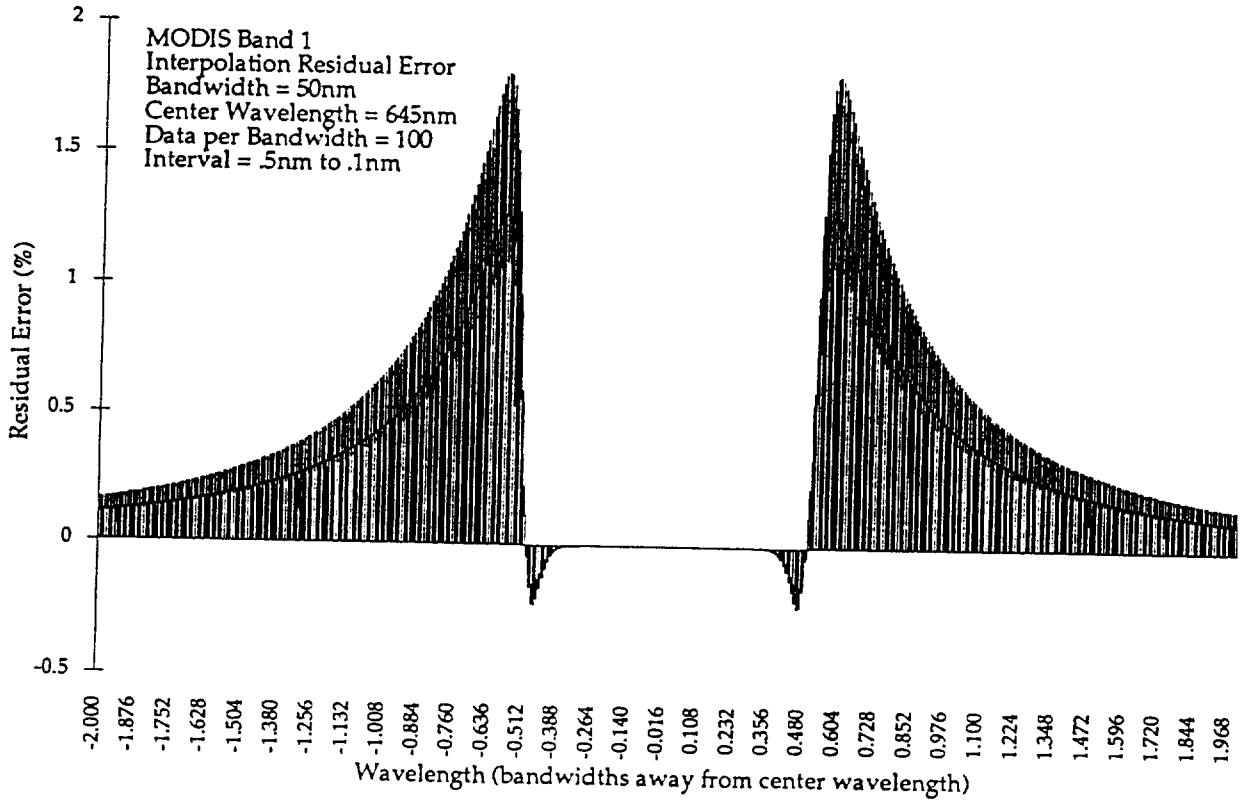
Band 1:	$Bw/i = 25$ results in $E_T = 20.1\%$
	$Bw/i = 50$ results in $E_T = 4.9\%$
	$Bw/i = 100$ results in $E_T = 1.2\%$
Band 4:	$Bw/i = 20$ results in $E_T = 7.1\%$
Band 8:	$Bw/i = 15$ results in $E_T = 12.7\%$
Band 9:	$Bw/i = 10$ results in $E_T = 12.2\%$
Band 18:	$Bw/i = 10$ results in $E_T = 3.4\%$
Band 32:	$Bw/i = 50$ results in $E_T = 1.5\%$
Band 36:	$Bw/i = 30$ results in $E_T = 1.2\%$

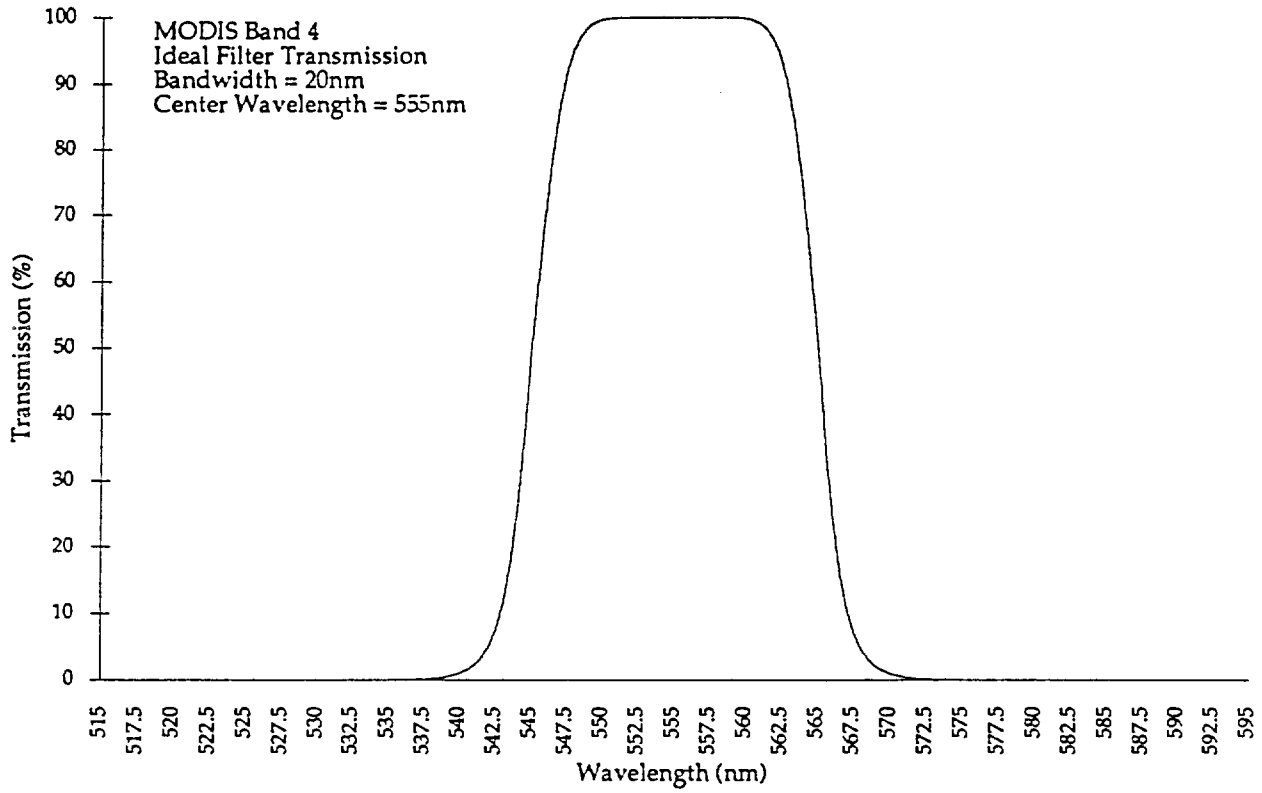
These results show several systematic trends. For all cases analyzed, the peak error occurs between -.75 bandwidths to -.54 bandwidths and between +.54 bandwidths to +.75 bandwidths. The number of data points per bandwidth must be sufficiently high to obtain low residual errors. Each MODIS band behaves in a way similar to, but not exactly the same as, the other MODIS bands. If beneficial to the current MODIS project, a more comprehensive analysis could be performed for all 36 MODIS bands at various initial resolutions. Attached are the resultant charts of this study.

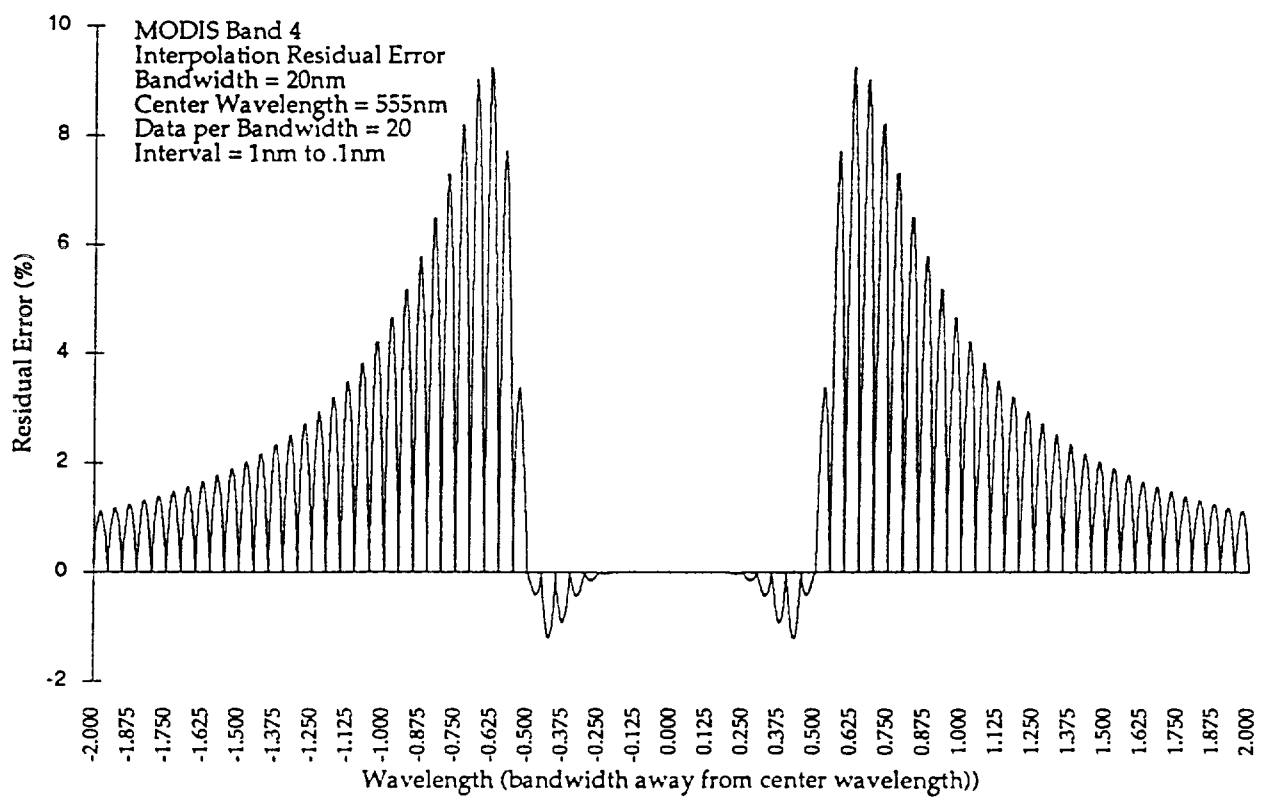

MODIS Band 1
Ideal Filter Transmission
Bandwidth = 50nm
Center Wavelength = 645nm
Transmission (%)
100
90
80
70
60
50
40
30
20
10
0
545
551.2
557.4
563.6
569.8
576
582.2
588.4
594.6
600.8
607
613.2
619.4
625.6
631.8
638
644.2
650.4
656.6
662.8
669
675.2
681.4
687.6
693.8
700
706.2
712.4
718.6
724.8
731
737.2
743.4
Wavelength (nm)

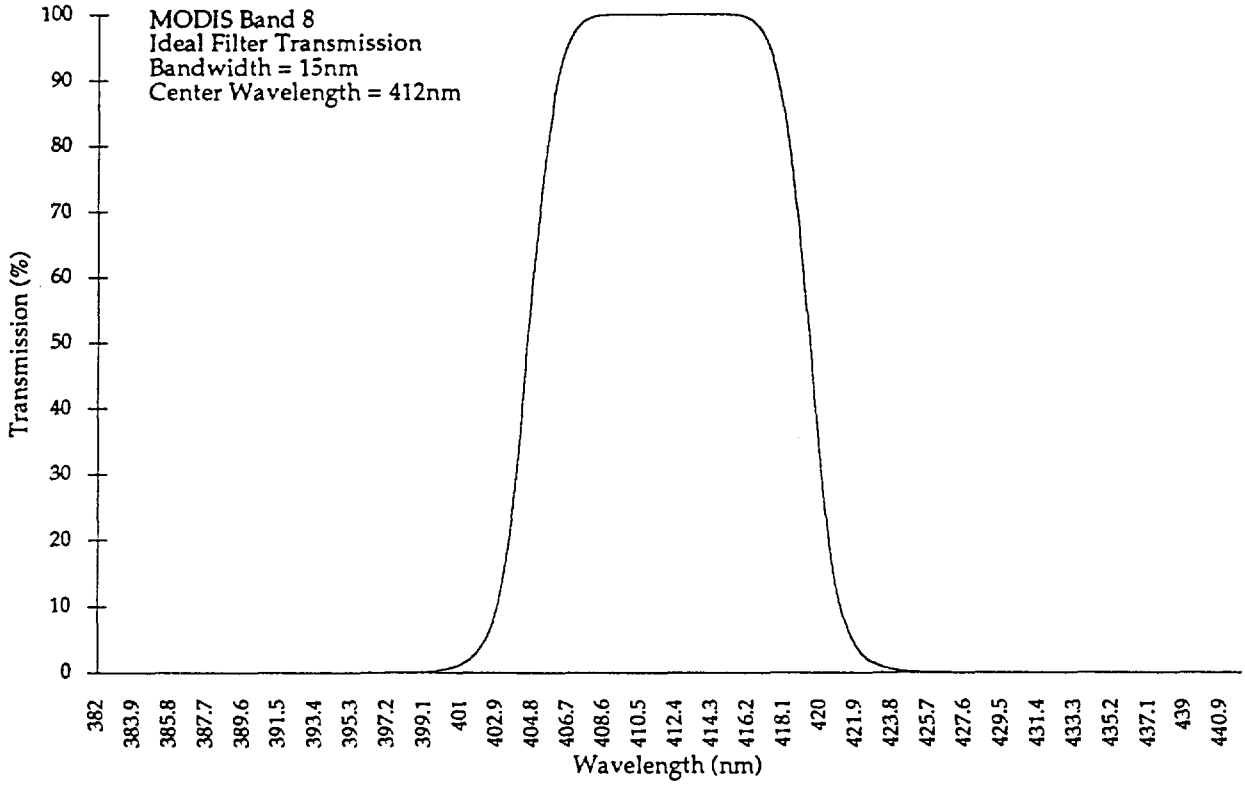

MODIS Band 1
Interpolation Residual Error
Bandwidth = 50nm
Center Wavelength = 645nm
Data per Bandwidth = 25
Interval = 2nm to .1nm
Residual Error (%)
35
30
25
20
15
10
5
0
-5
-2
-1.88
-1.75
-1.63
-1.5
-1.38
-1.26
-1.13
-1.01
-0.88
-0.76
-0.64
-0.51
-0.39
-0.26
-0.14
-0.02
0.11
0.23
0.36
0.48
0.6
0.73
0.85
0.98
1.1
1.22
1.35
1.47
1.6
1.72
1.84
1.97
Wavelength (bandwidths away from center wavelength)

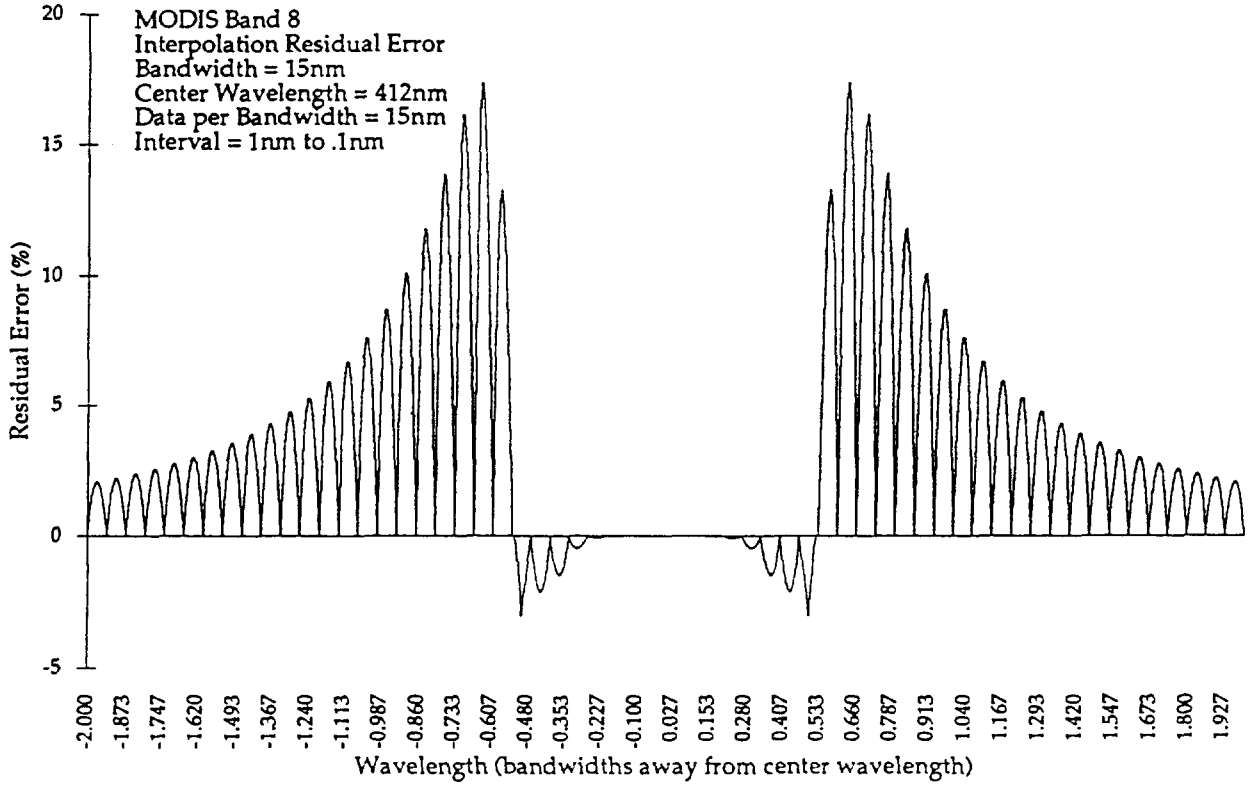

MODIS Band 1
Interpolation Residual Error
Bandwidth = 50nm
Center Wavelength = 645nm
Data per Bandwidth = 50
Interval = 1nm to .1nm
Residual Error (%)
8
7
6
5
4
3
2
1
0
-1
-2.000
-1.876
-1.752
-1.628
-1.504
-1.380
-1.256
-1.132
-1.008
-0.884
-0.760
-0.636
-0.512
-0.388
-0.264
-0.140
-0.016
0.108
0.232
0.356
0.480
0.604
0.728
0.852
0.976
1.100
1.224
1.348
1.472
1.596
1.720
1.844
1.968
Wavelength (bandwidths away from center wavelength)

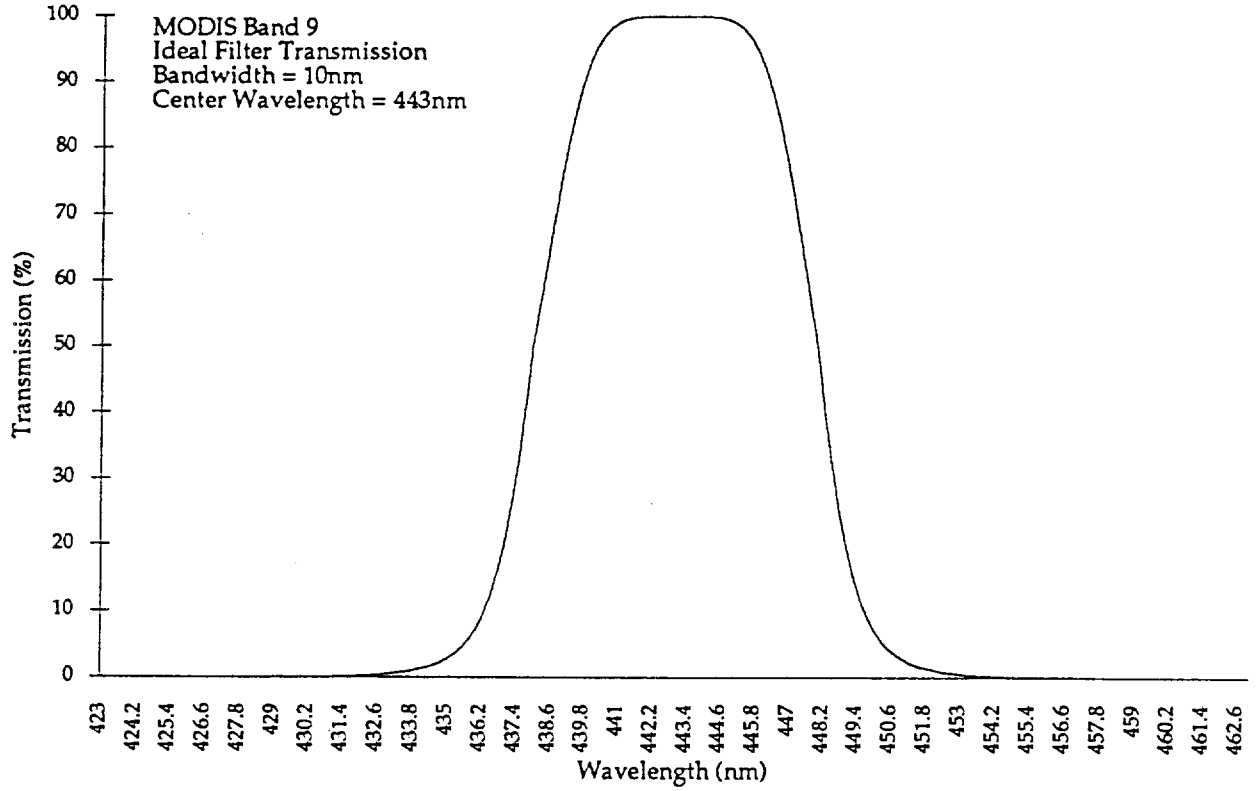

MODIS Band 1
Interpolation Residual Error
Bandwidth = 50nm
Center Wavelength = 645nm
Data per Bandwidth = 100
Interval = .5nm to .1nm
Residual Error (%)
2
1.5
1
0.5
0
-0.5
-2.000
-1.876
-1.752
-1.628
-1.504
-1.380
-1.256
-1.132
-1.008
-0.884
-0.760
-0.636
-0.512
-0.388
-0.264
-0.140
-0.016
0.108
0.232
0.356
0.480
0.604
0.728
0.852
0.976
1.100
1.224
1.348
1.472
1.596
1.720
1.844
1.968
Wavelength (bandwidths away from center wavelength)

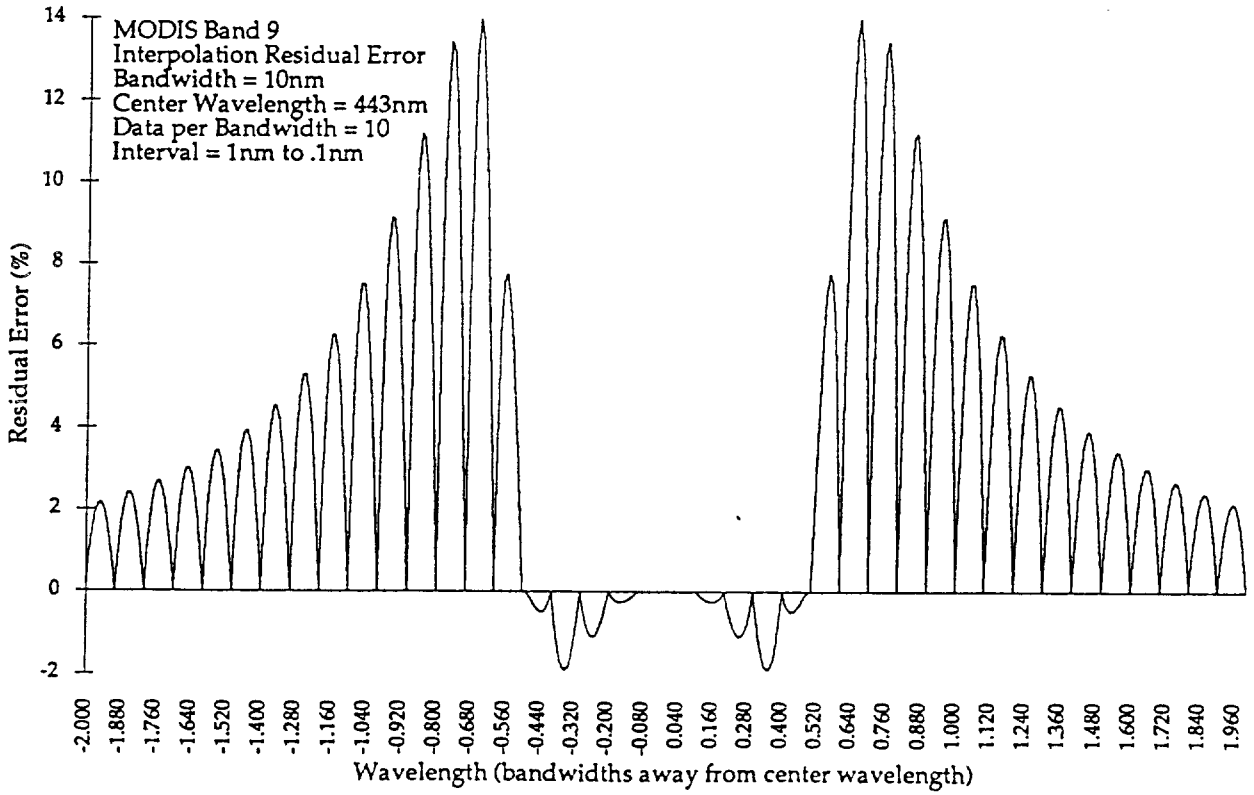

MODIS Band 4
Ideal Filter Transmission
Bandwidth = 20nm
Center Wavelength = 555nm
Transmission (%)
Wavelength (nm)

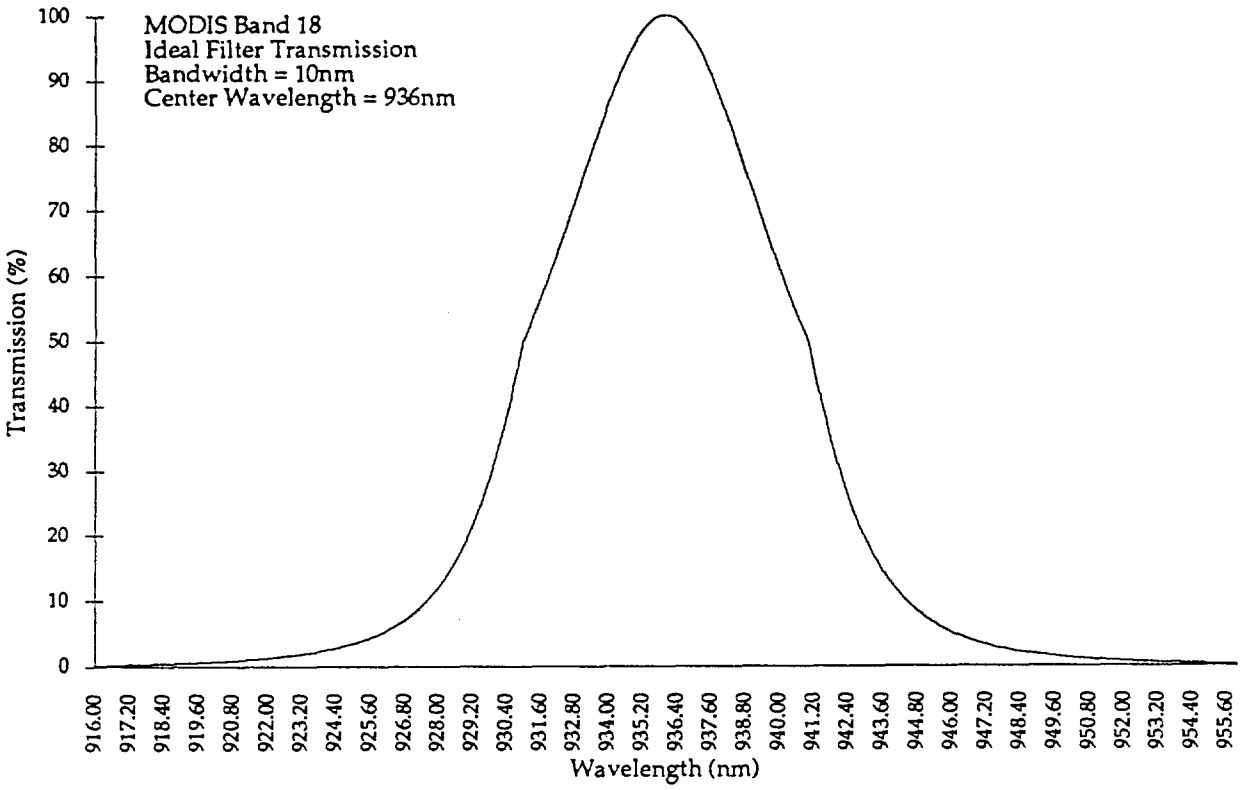

MODIS Band 4
Interpolation Residual Error
Bandwidth = 20nm
Center Wavelength = 555nm
Data per Bandwidth = 20
Interval = 1nm to .1nm
Residual Error (%)
Wavelength (bandwidth away from center wavelength))

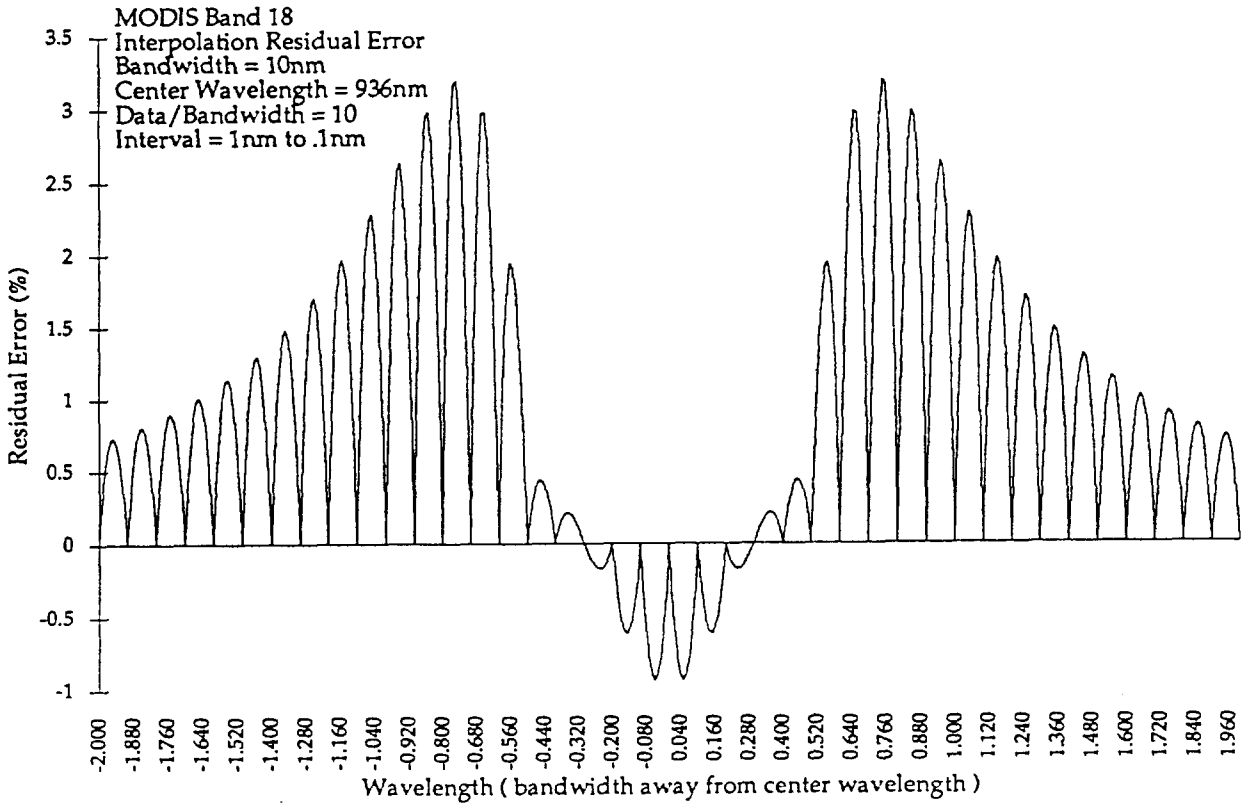

MODIS Band 8
Ideal Filter Transmission
Bandwidth = 15nm
Center Wavelength = 412nm
Transmission (%)
100
90
80
70
60
50
40
30
20
10
0
382
383.9
385.8
387.7
389.6
391.5
393.4
395.3
397.2
399.1
401
402.9
404.8
406.7
408.6
410.5
412.4
414.3
416.2
418.1
420
421.9
423.8
425.7
427.6
429.5
431.4
433.3
435.2
437.1
439
440.9
Wavelength (nm)

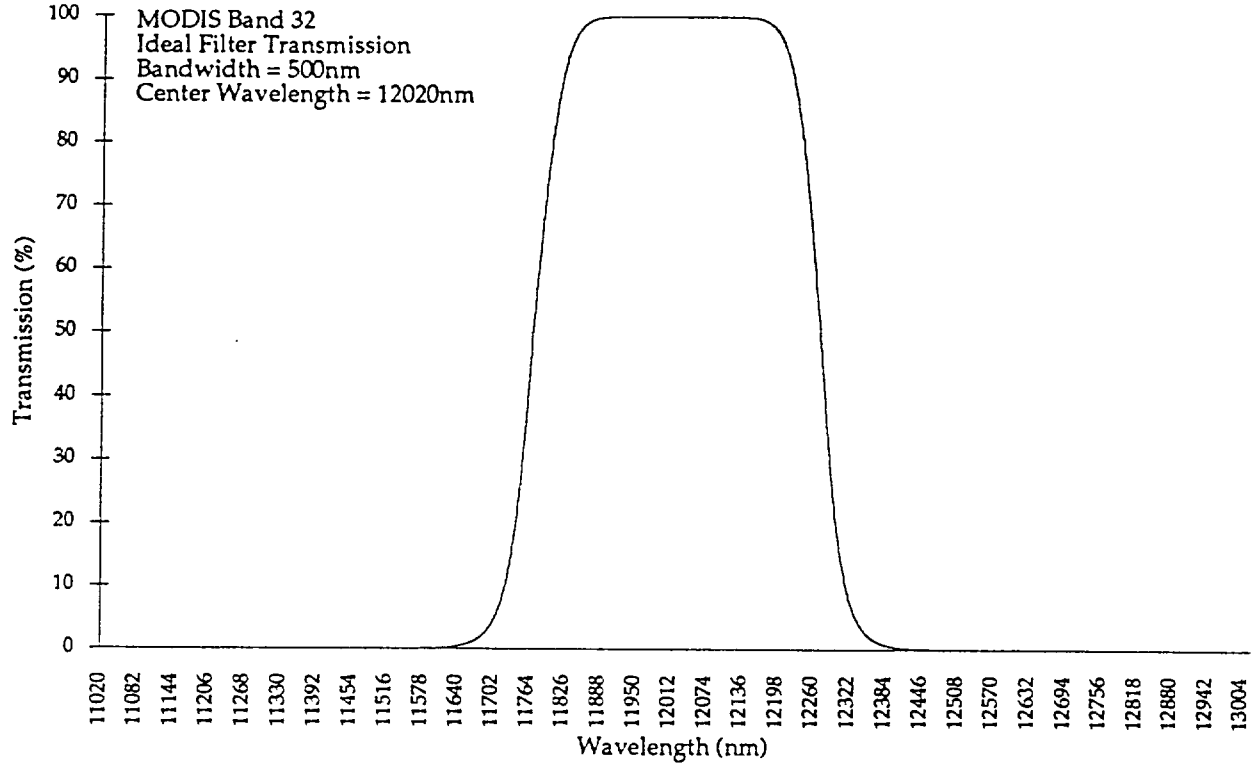

MODIS Band 8
Interpolation Residual Error
Bandwidth = 15nm
Center Wavelength = 412nm
Data per Bandwidth = 15nm
Interval = 1nm to .1nm
Residual Error (%)
20
15
10
5
0
-5
-2.000
-1.873
-1.747
-1.620
-1.493
-1.367
-1.240
-1.113
-0.987
-0.860
-0.733
-0.607
-0.480
-0.353
-0.227
-0.100
0.027
0.153
0.280
0.407
0.533
0.660
0.787
0.913
1.040
1.167
1.293
1.420
1.547
1.673
1.800
1.927
Wavelength (bandwidths away from center wavelength)

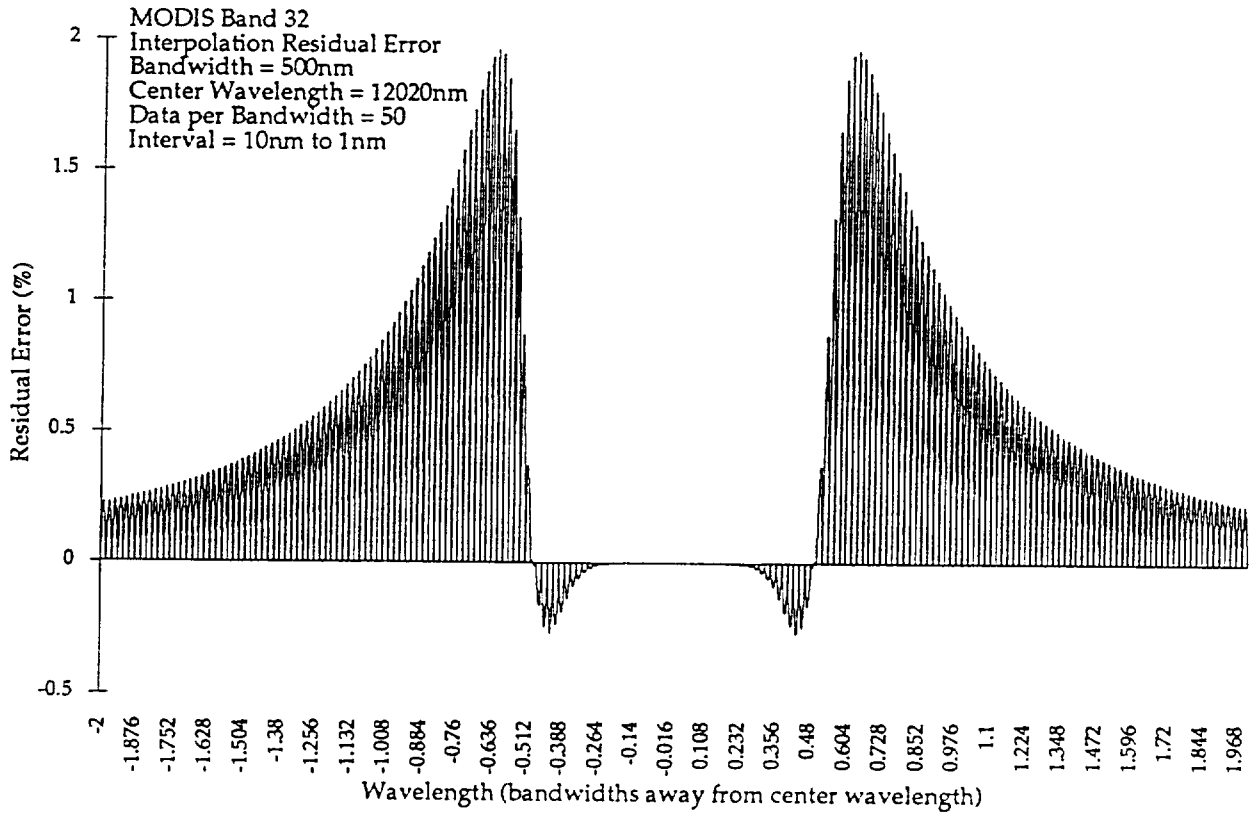

MODIS Band 9
Ideal Filter Transmission
Bandwidth = 10nm
Center Wavelength = 443nm
Transmission (%)
100
90
80
70
60
50
40
30
20
10
0
423
424.2
425.4
426.6
427.8
429
430.2
431.4
432.6
433.8
435
436.2
437.4
438.6
439.8
441
442.2
443.4
444.6
445.8
447
448.2
449.4
450.6
451.8
453
454.2
455.4
456.6
457.8
459
460.2
461.4
462.6
Wavelength (nm)

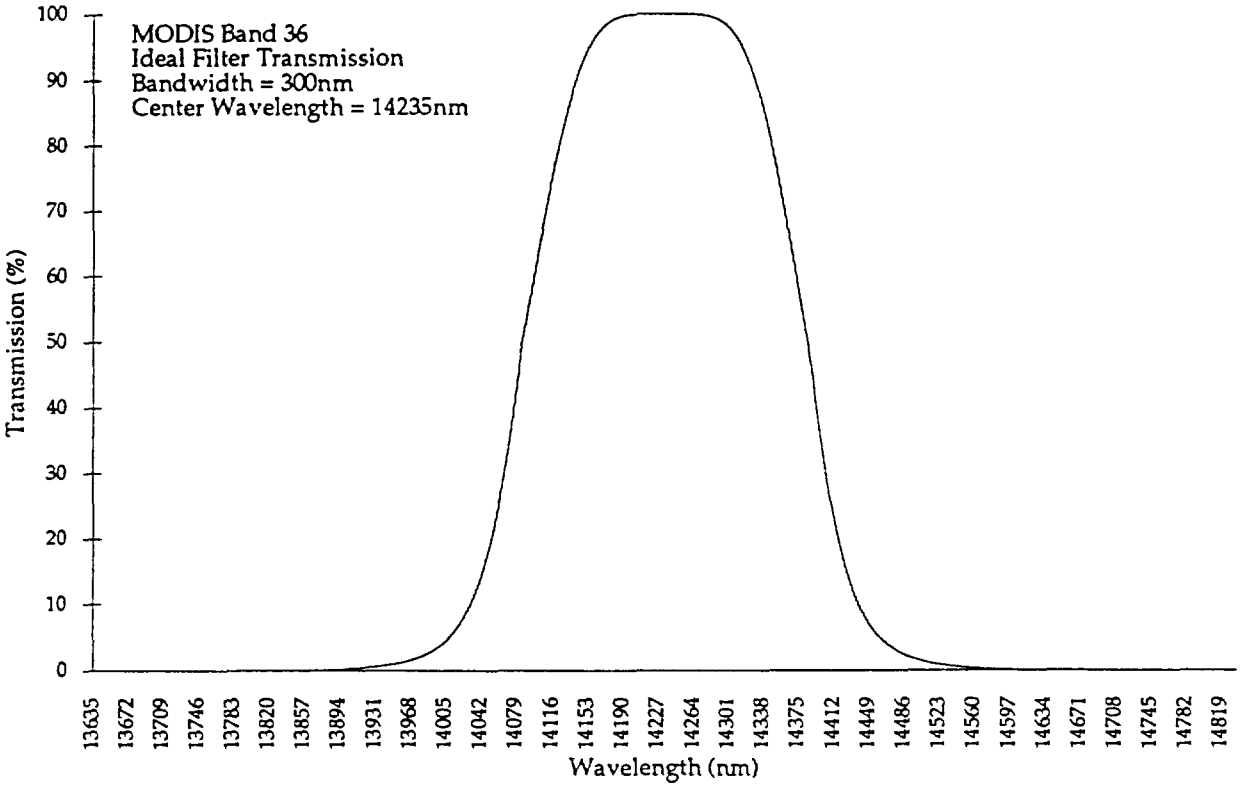

MODIS Band 9
Interpolation Residual Error
Bandwidth = 10nm
Center Wavelength = 443nm
Data per Bandwidth = 10
Interval = 1nm to .1nm
Residual Error (%)
14
12
10
8
6
4
2
0
-2
-2.000
-1.880
-1.760
-1.640
-1.520
-1.400
-1.280
-1.160
-1.040
-0.920
-0.800
-0.680
-0.560
-0.440
-0.320
-0.200
-0.080
0.040
0.160
0.280
0.400
0.520
0.640
0.760
0.880
1.000
1.120
1.240
1.360
1.480
1.600
1.720
1.840
1.960
Wavelength (bandwidths away from center wavelength)

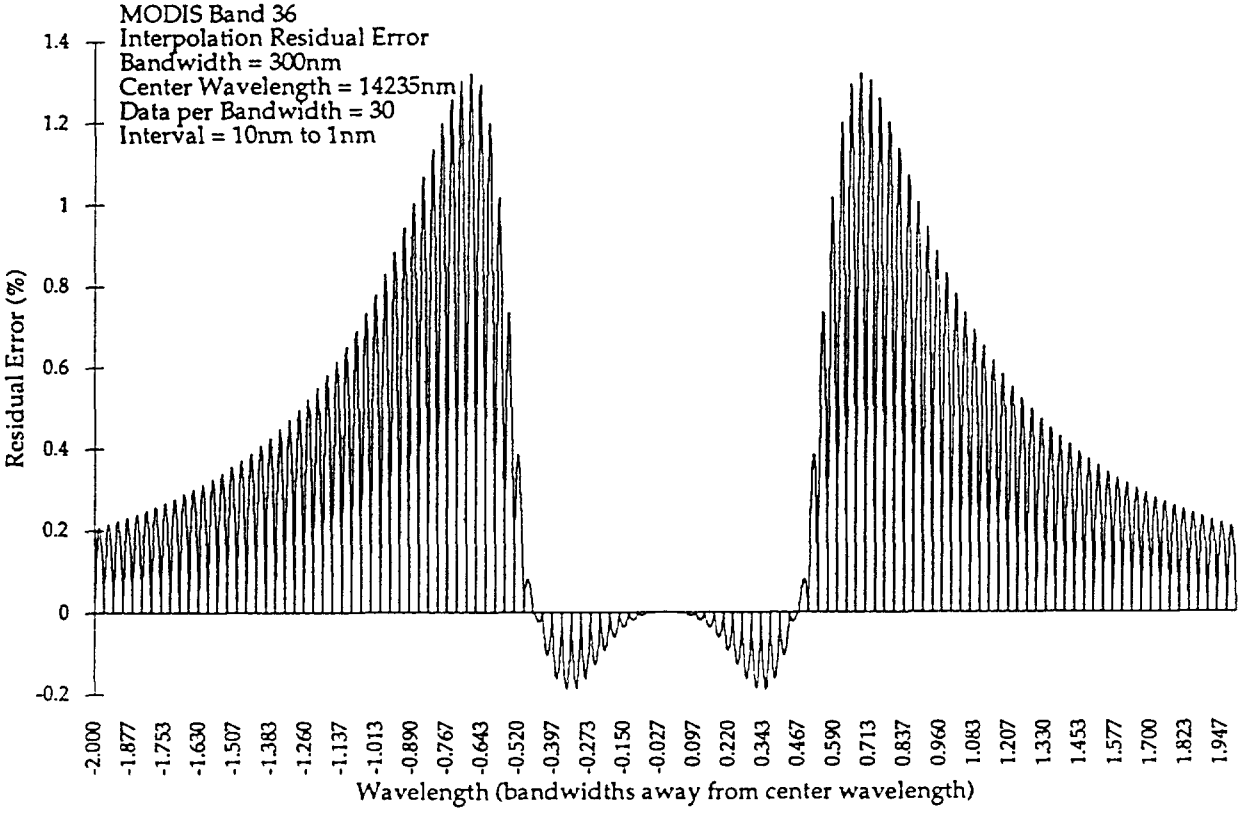

MODIS Band 18
Ideal Filter Transmission
Bandwidth = 10nm
Center Wavelength = 936nm
Transmission (%)
100
90
80
70
60
50
40
30
20
10
0
916.00
917.20
918.40
919.60
920.80
922.00
923.20
924.40
925.60
926.80
928.00
929.20
930.40
931.60
932.80
934.00
935.20
936.40
937.60
938.80
940.00
941.20
942.40
943.60
944.80
946.00
947.20
948.40
949.60
950.80
952.00
953.20
954.40
955.60
Wavelength (nm)


MODIS Band 18
Interpolation Residual Error
Bandwidth = 10nm
Center Wavelength = 936nm
Data/Bandwidth = 10
Interval = 1nm to .1nm
Residual Error (%)
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-2.000
-1.880
-1.760
-1.640
-1.520
-1.400
-1.280
-1.160
-1.040
-0.920
-0.800
-0.680
-0.560
-0.440
-0.320
-0.200
-0.080
0.040
0.160
0.280
0.400
0.520
0.640
0.760
0.880
1.000
1.120
1.240
1.360
1.480
1.600
1.720
1.840
1.960
Wavelength (bandwidth away from center wavelength)


MODIS Band 32
Ideal Filter Transmission
Bandwidth = 500nm
Center Wavelength = 12020nm
Transmission (%)
100
90
80
70
60
50
40
30
20
10
0
11020
11082
11144
11206
11268
11330
11392
11454
11516
11578
11640
11702
11764
11826
11888
11950
12012
12074
12136
12198
12260
12322
12384
12446
12508
12570
12632
12694
12756
12818
12880
12942
13004
Wavelength (nm)


MODIS Band 32
Interpolation Residual Error
Bandwidth = 500nm
Center Wavelength = 12020nm
Data per Bandwidth = 50
Interval = 10nm to 1nm
Residual Error (%)
2
1.5
1
0.5
0
-0.5
-2
-1.876
-1.752
-1.628
-1.504
-1.38
-1.256
-1.132
-1.008
-0.884
-0.76
-0.636
-0.512
-0.388
-0.264
-0.14
-0.016
0.108
0.232
0.356
0.48
0.604
0.728
0.852
0.976
1.1
1.224
1.348
1.472
1.596
1.72
1.844
1.968
Wavelength (bandwidths away from center wavelength)


MODIS Band 36
Ideal Filter Transmission
Bandwidth = 300nm
Center Wavelength = 14235nm
Transmission (%)
100
90
80
70
60
50
40
30
20
10
0
13635
13672
13709
13746
13783
13820
13857
13894
13931
13968
14005
14042
14079
14116
14153
14190
14227
14264
14301
14338
14375
14412
14449
14486
14523
14560
14597
14634
14671
14708
14745
14782
14819
Wavelength (nm)


MODIS Band 36
Interpolation Residual Error
Bandwidth = 300nm
Center Wavelength = 14235nm
Data per Bandwidth = 30
Interval = 10nm to 1nm
Residual Error (%)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-2.000
-1.877
-1.753
-1.630
-1.507
-1.383
-1.260
-1.137
-1.013
-0.890
-0.767
-0.643
-0.520
-0.397
-0.273
-0.150
-0.027
0.097
0.220
0.343
0.467
0.590
0.713
0.837
0.960
1.083
1.207
1.330
1.453
1.577
1.700
1.823
1.947
Wavelength (bandwidths away from center wavelength)