2016.7.28　東京、日経カンファレンスルーム
第2回先進光学衛星利用ワークショップ

陸域植生分野での追加バンドの利用

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植生状況把握へのWorldView-2/Red Edgeバンドの利用
2016.5.28　システム農学会　in　福岡

陸域植生分野での追加バンドの利用

WorldView-2/Coastal, Yellow, Red Edge, NIR2 バンドの特性解明

1. はじめに
2. 主な衛星光学センサ
3. バンド間相関
4. 判別効率表および分離度による評価
5. Red Edgeの利用例
6. 結論

陸域植生分野での追加バンドの利用

I. はじめに

目的

LANDSAT/MSSおよびAVNIR2の4バンドで十分か？

内容

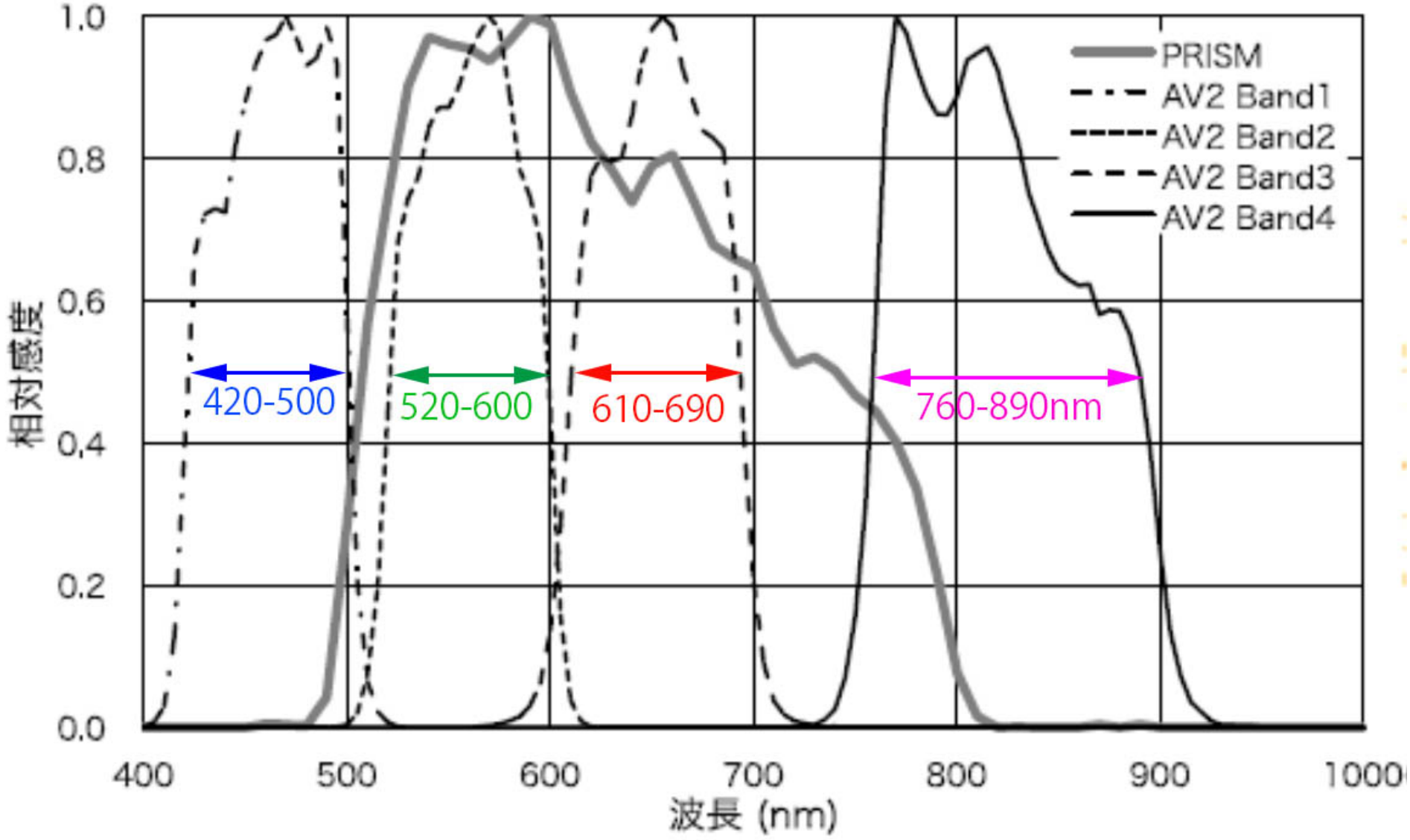
AVNIRの4バンドに数バンド追加することの意義と適正バンドを、WorldView2を例に明らかにする。

2. 主な衛星光学センサ

マルチスペクトルセンサ（MSS)の各バンドの必要条件

汎用目的の場合

① 十分なS/N比があること。
　　→バンド幅が広いほど有利
② 他のバンドとの相関が低いこと
　　→バンド幅が狭いほど有利
③ 大気条件による影響を避けるため、出来るだけ、水分等の吸収帯が入らないようにすること



PRISMとAVNIR-2の分光応答

松岡真如 ALOSの光学センサを用いたパンシャープン処理
第4回 ALOS-2/3ワークショップ H24.12.12-13

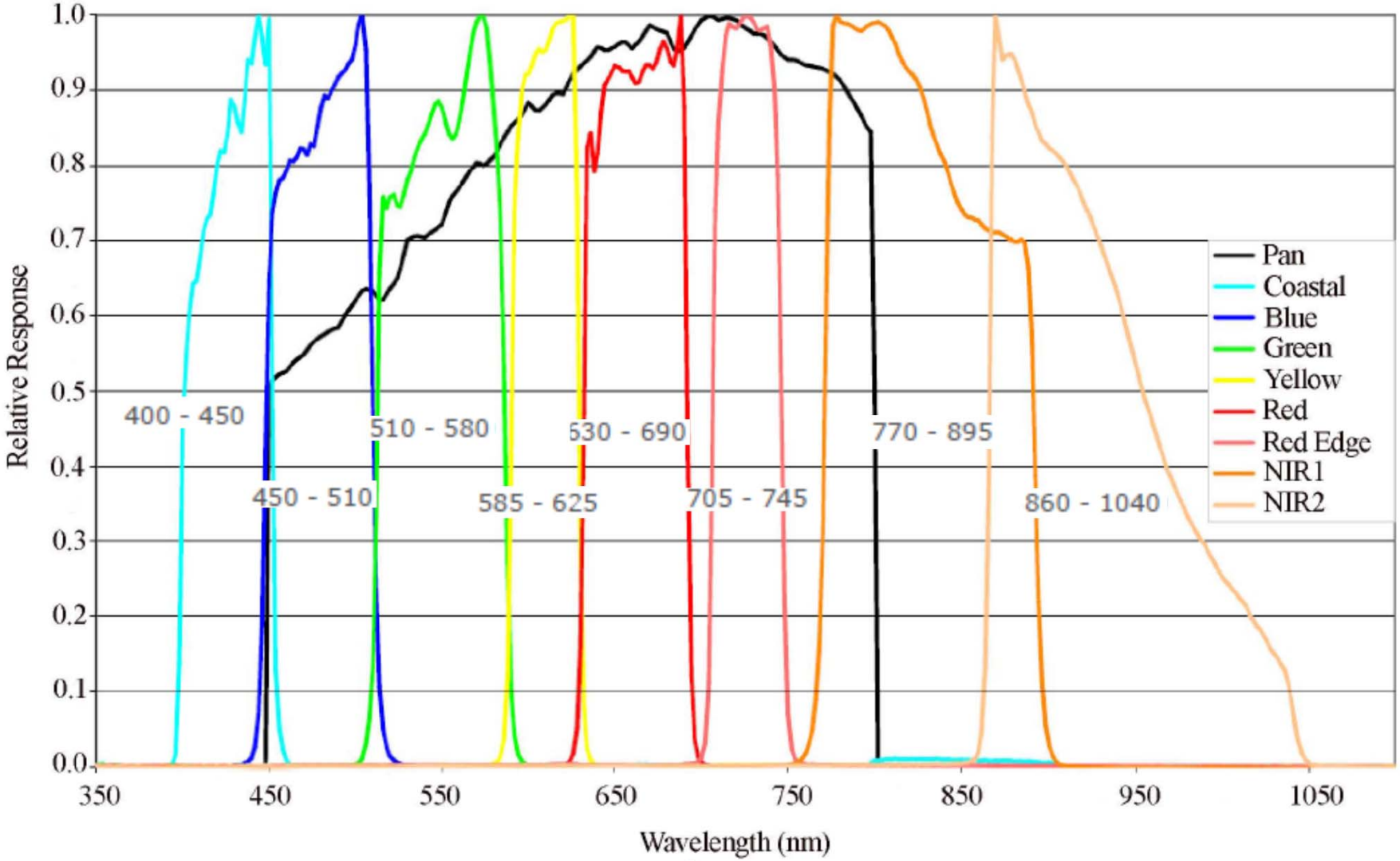


Figure 2. Spectral response of the WorldView-2 Sensor[1]. (for color image please see electronic version)

WorldView-2 data simulation and analysis results

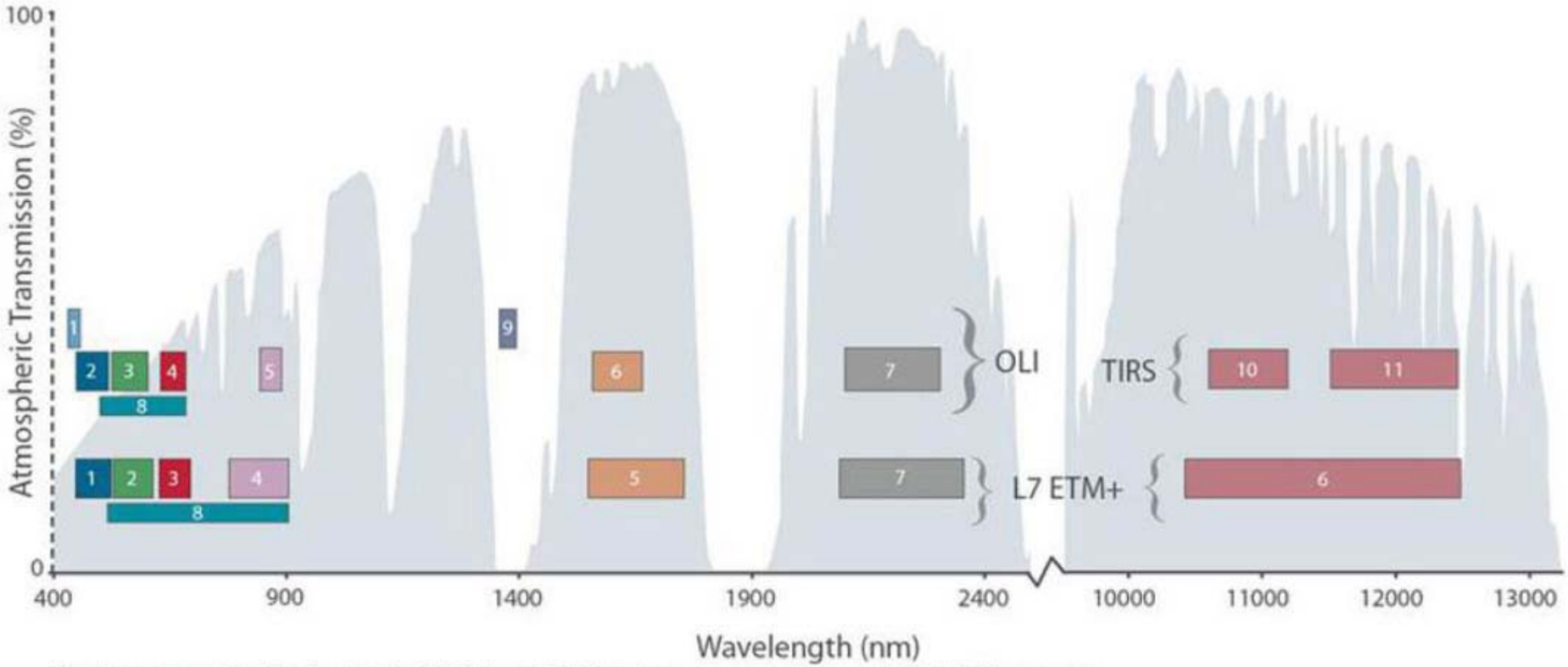
Algorithms and Technologies for Multispectral, Hyperspectral, and Ultraspectral Imagery XV, edited by Sylvia S. Shen, Paul E. Lewis, Proc. of SPIE Vol. 7334, 73340U · © 2009 SPIE

WorldView-3

launched in August 2014

Sensor Bands	Panchromatic: 450 - 800 nm 8 Multispectral: Coastal: 400 - 450 nm Blue: 450 - 510 nm Green: 510 - 580 nm Yellow: 585 - 625 nm Red: 630 - 690 nm Red Edge: 705 - 745 nm Near-IR1: 770 - 895 nm Near-IR2: 860 - 1040 nm 8 SWIR Bands: SWIR-1: 1195 - 1225 nm SWIR-2: 1550 - 1590 nm SWIR-3: 1640 - 1680 nm SWIR-4: 1710 - 1750 nm SWIR-5: 2145 - 2185 nm SWIR-6: 2185 - 2225 nm SWIR-7: 2235 - 2285 nm SWIR-8: 2295 - 2365 nm 12 CAVIS Bands: Desert Clouds: 405 - 420 nm Aerosol-1: 459 - 509 nm Green: 525 - 585 nm Aerosol-2: 620 - 670 nm Water-1: 845 - 885 nm Water-2: 897 - 927 nm Water-3: 930 - 965 nm NDVI-SWIR: 1220 - 1252 nm Cirrus: 1350 - 1410 nm Snow: 1620 - 1680 nm Aerosol-3: 2105 - 2245 nm Aerosol-3: 2105 - 2245 nm
Dynamic Range	11-bits per pixel Pan and MS; 14-bits per pixel SWIR
Swath Width	At nadir: 13.1 km
Sensor Resolution (or GSD, Ground Sample Distance; off-nadir is geometric mean)	Panchromatic Nadir: 0.31 m Multispectral Nadir: 1.24 m SWIR Nadir: 3.70 m CAVIS Nadir: 30.00 m

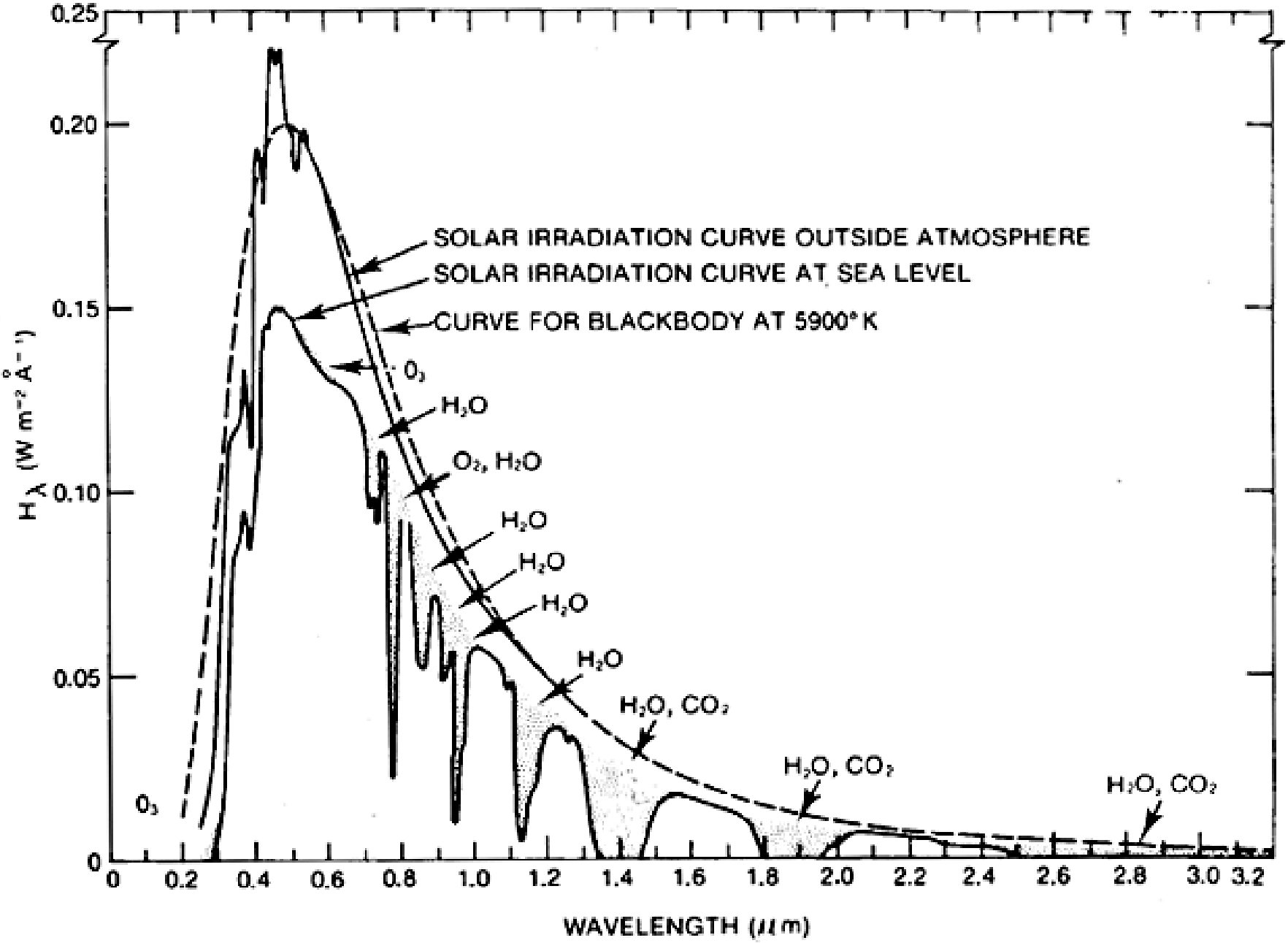
太陽光の大気透過率と観測バンド　Landsat8の場合



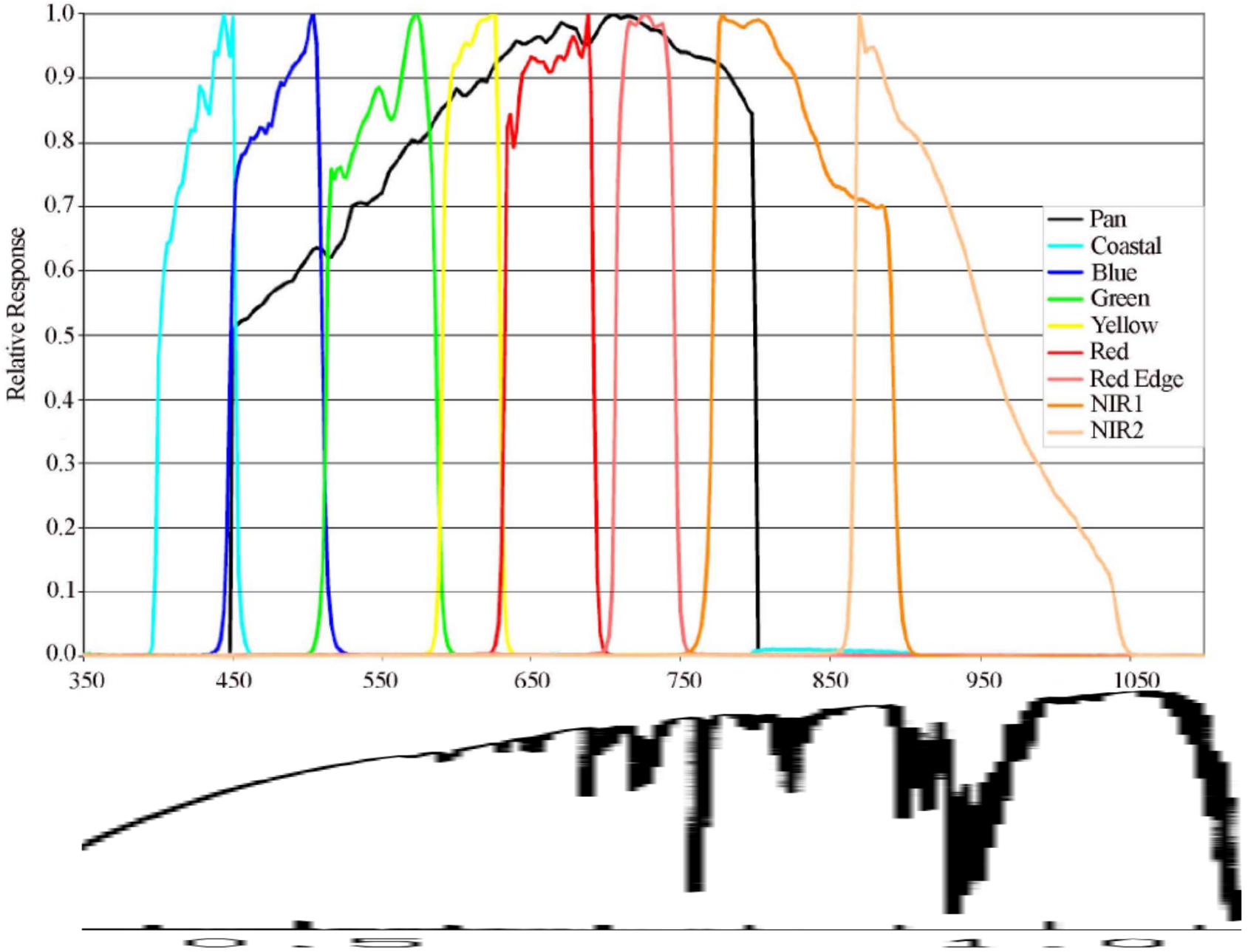
Bandpass wavelengths for Landsat 8 OLI and TIRS sensor, compared to Landsat 7 ETM+ sensor

Note: atmospheric transmission values for this graphic were calculated using MODTRAN for a summertime mid-latitude hazy atmosphere (circa 5 km visibility).

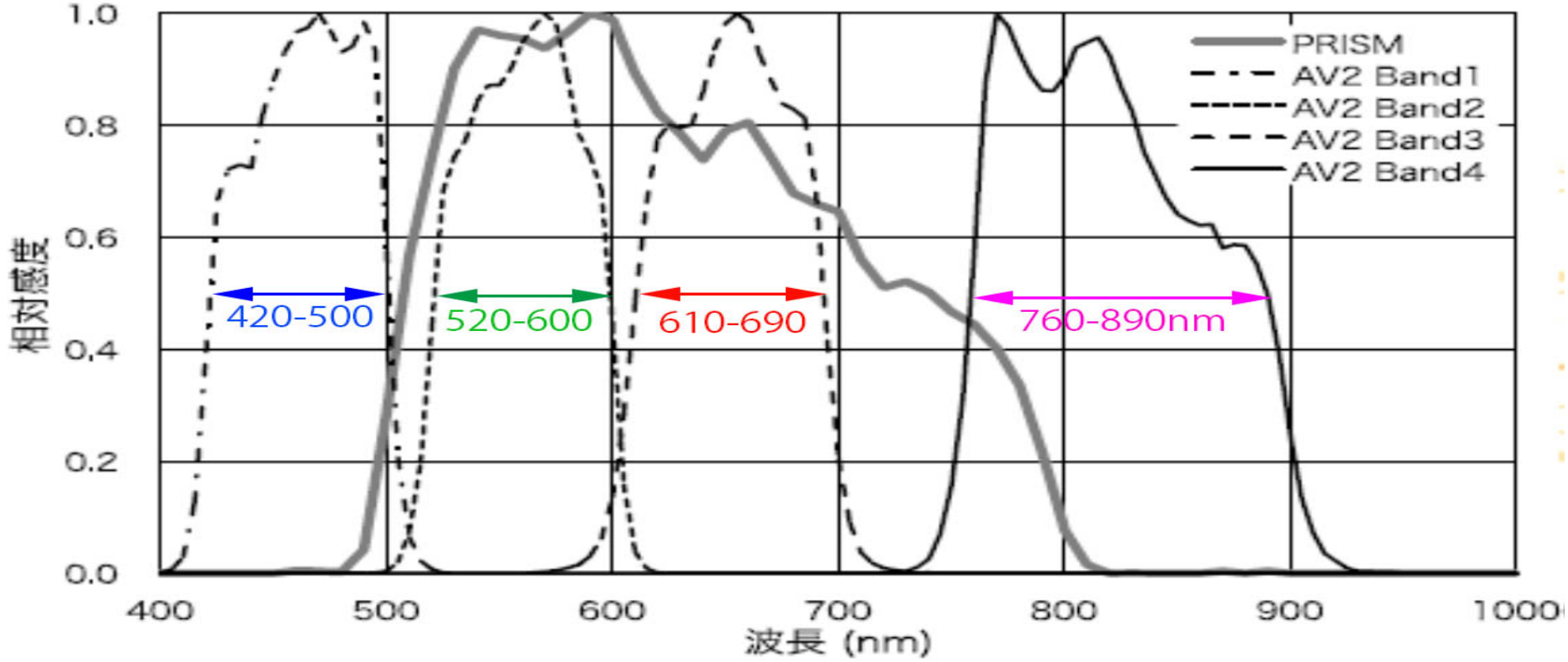
地上伝達太陽光

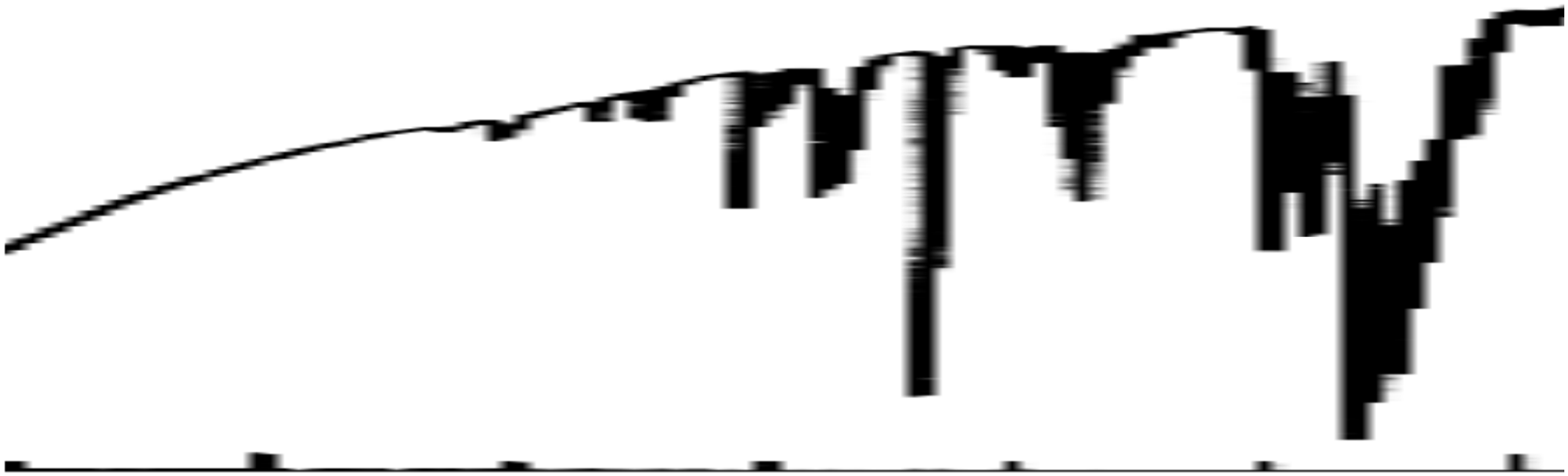

0.25
0.20
0.15
0.10
0.05
0
H_λ (W m^{-2} Å^{-1})
SOLAR IRRADIATION CURVE OUTSIDE ATMOSPHERE
SOLAR IRRADIATION CURVE AT SEA LEVEL
CURVE FOR BLACKBODY AT 5900° K
O_3
H_2O
O_2, H_2O
H_2O
H_2O
H_2O
H_2O
H_2O, CO_2
H_2O, CO_2
H_2O, CO_2
O_3
0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4 2.6 2.8 3.0 3.2
WAVELENGTH (μm)

地上伝達太陽光強度とWV2バンド



地上伝達太陽光強度とAVNIR2バンド





WorldView2 4 New Bands

Coastal

- chlorophyll absorption, blue light scattering, water depth, “true-color”; will support coastline water depth studies based upon its chlorophyll and water penetration characteristics. Also, this band is subject to some atmospheric scattering and is investigated to examine atmospheric correction techniques. クロロフィル吸収、青色光散乱、「実際の色」は、クロロフィルと水の透過特性に基づく海岸線の水深研究をサポートする。また、このバンドは大気散乱に関係しており、大気補正研究を推進する

Yellow

- important for vegetation and turbidity applications. Also, this band will assist in the development of "true-color" hue correction for human vision representation. 植生と濁り関連に重要である。また、このバンドは、人間が見る「実際の色」の色相補正をするのに助ける。

Red Edge

- aids in the analysis of vegetation and vegetative condition. Directly related to plant health revealed through chlorophyll production. 植生と植生環境を解析するのを助ける。クロロフィル生産に関連して植物の健康に直接関連する。

NIR2

- overlaps the NIR1 band, supports vegetation analysis, materials differentiation and biomass studies; may help with atmospheric correction NIR1とオーバーラップしており、植生解析、物質の分類、バイオマス研究をサポートする。また、大気補正を助ける。

3. バンド間相関の検討 L8 OLI

バンド間相関の高いバンドを2つ使っても、
1バンド使用と同じ効果しかない。

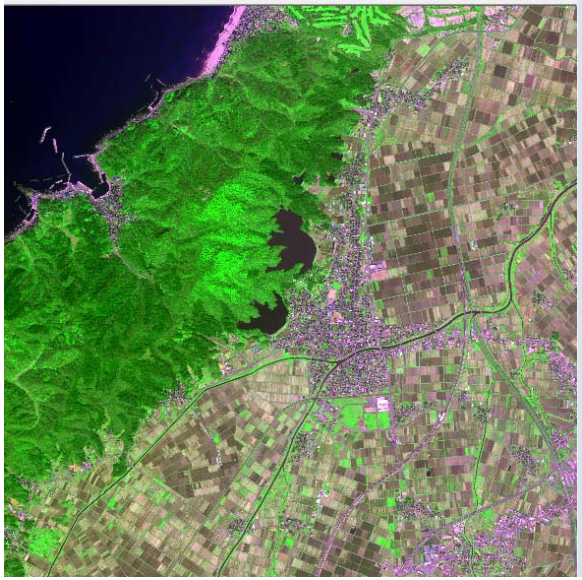
R:Red
G:Green
B:Blue

R:SWIR1
G:NIR
B:Red

Table 1　LANDSAT8/OLI 鶴岡画像（2013.9.27）についての各バンド間相関

Layer	1 Coast. aero.	2 Blue	3 Green	4 Red	5 NIR	6 SWIR1	7 SWIR2
1	1.00000	0.97700	0.81537	0.82041	0.03587	0.68077	0.83632
2	0.97700	1.00000	0.89303	0.91559	0.14586	0.78042	0.88652
3	0.81537	0.89303	1.00000	0.96168	0.49184	0.85811	0.83716
4	0.82041	0.91559	0.96168	1.00000	0.37392	0.88240	0.88343
5	0.03587	0.14586	0.49184	0.37392	1.00000	0.55591	0.25422
6	0.68077	0.78042	0.85811	0.88240	0.55591	1.00000	0.92290
7	0.83632	0.88652	0.83716	0.88343	0.25422	0.92290	1.00000

バンド間相関の検討WV2



R:Red
G:NIR1
B:Blue

R:Red Edge
G:NIR2
B:Yellow

Table 2　WorldView2　　鶴岡西部エリア（2014.04.29）についての各バンド間相関

Layer	1. Coastal	2. Blue	3. Green	4. Yellow	5. Red	6. Red Edge	7. NIR1	8. NIR2
1	1.00000	0.98527	0.93857	0.91259	0.89835	0.54744	0.32054	0.30145
2	0.98527	1.00000	0.96366	0.93752	0.93204	0.58683	0.36186	0.34347
3	0.93857	0.96366	1.00000	0.98161	0.96997	0.75457	0.55436	0.53508
4	0.91259	0.93752	0.98161	1.00000	0.99224	0.76490	0.55626	0.54388
5	0.89835	0.93204	0.96997	0.99224	1.00000	0.73419	0.52266	0.51210
6	0.54744	0.58683	0.75457	0.76490	0.73419	1.00000	0.95401	0.94615
7	0.32054	0.36186	0.55436	0.55626	0.52266	0.95401	1.00000	0.99264
8	0.30145	0.34347	0.53508	0.54388	0.51210	0.94615	0.99264	1.00000

バンド間相関の検討 WV2

R:Red
G:NIR1
B:Blue

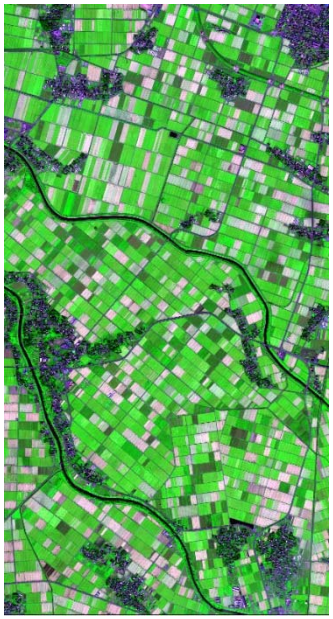
R:Yellow
G:Red Edge
B:Coastal

R:Red Edge
G:NIR2
B:Yellow

Table 3　WorldView2　　鶴岡北部エリア（2014.06.29）についての各バンド間相関

Layer	1. Coastal	2. Blue	3. Green	4. Yellow	5. Red	6. Red Edge	7. NIR1	8. NIR2
1	1.00000	0.98748	0.96426	0.95514	0.94078	0.51030	-0.01591	0.06413
2	0.98748	1.00000	0.98115	0.96950	0.96535	0.52128	-0.01558	0.06831
3	0.96426	0.98115	1.00000	0.97901	0.97209	0.63257	0.10180	0.18126
4	0.95514	0.96950	0.97901	1.00000	0.99299	0.53949	-0.02181	0.06323
5	0.94078	0.96535	0.97209	0.99299	1.00000	0.50679	-0.05554	0.03217
6	0.51030	0.52128	0.63257	0.53949	0.50679	1.00000	0.81031	0.85004
7	-0.01591	-0.01558	0.10180	-0.02181	-0.05554	0.81031	1.00000	0.98082
8	0.06413	0.06831	0.18126	0.06323	0.03217	0.85004	0.98082	1.00000

バンド間相関の検討



R:Red
G:NIR1
B:Blue

R:Yellow
G:Red Edge
B:Coastal

R:Red Edge
G:NIR2
B:Yellow

Table 4　WorldView2　　鶴岡北部エリア（2014.09.13）についての各バンド間相関

Layer	1. Coastal	2. Blue	3. Green	4. Yellow	5. Red	6. Red Edge	7. NIR1	8. NIR2
1	1.00000	0.93377	0.73819	0.71041	0.73246	0.19798	0.00904	0.03953
2	0.93377	1.00000	0.87792	0.87742	0.91038	0.36037	0.14488	0.18794
3	0.73819	0.87792	1.00000	0.97724	0.92858	0.73144	0.53037	0.55923
4	0.71041	0.87742	0.97724	1.00000	0.97339	0.68616	0.46422	0.50573
5	0.73246	0.91038	0.92858	0.97339	1.00000	0.55360	0.32883	0.38033
6	0.19798	0.36037	0.73144	0.68616	0.55360	1.00000	0.95065	0.95646
7	0.00904	0.14488	0.53037	0.46422	0.32883	0.95065	1.00000	0.99203
8	0.03953	0.18794	0.55923	0.50573	0.38033	0.95646	0.99203	1.00000

４．判別効率表および分離度による評価

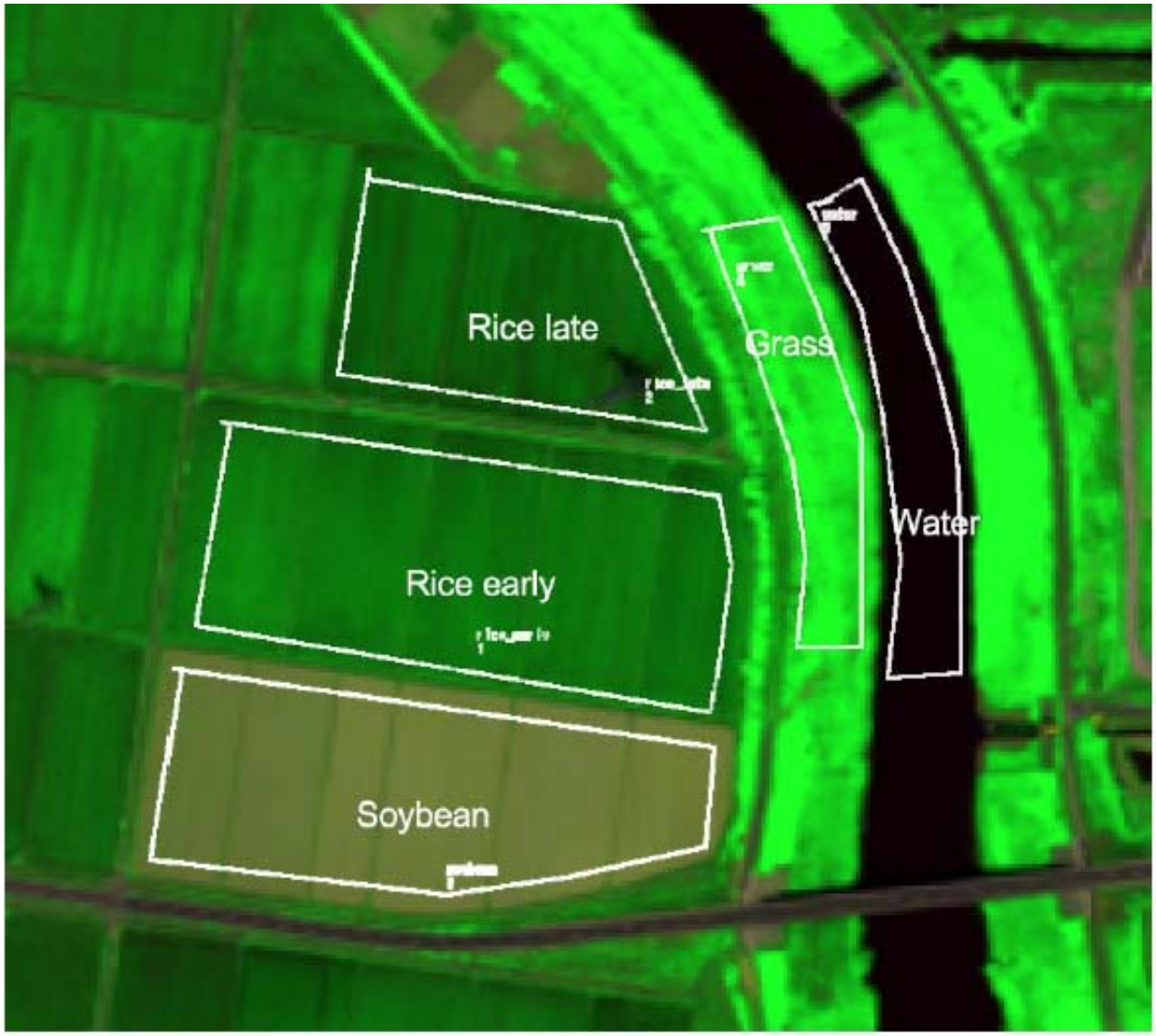


Fig.9　WorldView2（鶴岡、2014.06.29）と Training Fields　（R:Red, G:NIR1, B:Blue）

Table 5　WorldView2（鶴岡, 2014.06.29）での土地被覆分類における使用バンドによる判別効率

Bands used: 1:Coastal, 2:Blue, 3:Green, 4:Yellow, 5:Red, 6:Red edge, 7:NIR1, 8:NIR2
Classes used: 1: rice early 2: rice late 3: soybean 4: grass 5: water

(A) 2:Blue, 3:Green, 5:Red, 7:NIR1
TRAINING CLASS PERFORMANCE (Resubstitution Method) (Channels used: 2-3,5,7)

Project Class Name	Class Number	Reference Accuracy+ (%)	Number Samples	Number of Samples in Class 1 rice_early	2 rice_late	3 soybean	4 grass	5 water
rice_early	1	93.7	5796	5430	366	0	0	0
rice_late	2	82.0	3254	587	2667	0	0	0
soybean	3	100.0	4870	0	0	4870	0	0
grass	4	100.0	1561	0	0	0	1561	0
water	5	100.0	1645	0	0	0	0	1645
TOTAL			17126	6017	3033	4870	1561	1645
Reliability Accuracy (%)*				90.2	87.9	100.0	100.0	100.0

OVERALL CLASS PERFORMANCE (16173 / 17126) = 94.4%　Kappa Statistic (X100) = 92.6%, Kappa Variance = 0.000006.

(B) 1:Coastal, 2:Blue, 3:Green, 4:Yellow, 5:Red, 6:Red edge, 7:NIR1, 8:NIR2
TRAINING CLASS PERFORMANCE (Resubstitution Method) (Channels used: 1-8)

Project Class Name	Class Number	Reference Accuracy+ (%)	Number Samples	Number of Samples in Class 1 rice_early	2 rice_late	3 soybean	4 grass	5 water
rice_early	1	94.8	5796	5497	299	0	0	0
rice_late	2	90.0	3254	327	2927	0	0	0
soybean	3	100.0	4870	0	0	4870	0	0
grass	4	100.0	1561	0	0	0	1561	0
water	5	100.0	1645	0	0	0	0	1645
TOTAL			17126	5824	3226	4870	1561	1645
Reliability Accuracy (%)*				94.4	90.7	100.0	100.0	100.0

OVERALL CLASS PERFORMANCE (16500 / 17126) = 96.3%　Kappa Statistic (X100) = 95.1%, Kappa Variance = 0.000004.

(E) (A) + 6:Red edge
TRAINING CLASS PERFORMANCE (Resubstitution Method) (Channels used: 2-3,5-7)

Project Class Name	Class Number	Reference Accuracy+ (%)	Number Samples	Number of Samples in Class 1 rice_early	2 rice_late	3 soybean	4 grass	5 water
rice_early	1	93.8	5796	5436	358	0	2	0
rice_late	2	82.8	3254	561	2693	0	0	0
soybean	3	100.0	4870	0	0	4870	0	0
grass	4	100.0	1561	0	0	0	1561	0
water	5	100.0	1645	0	0	0	0	1645
TOTAL			17126	5997	3051	4870	1563	1645
Reliability Accuracy (%)*				90.6	88.3	100.0	99.9	100.0

OVERALL CLASS PERFORMANCE (16205 / 17126) = 94.6%　Kappa Statistic (X100) = 92.8%, Kappa Variance = 0.000005.

(F) (A) + 8:NIR2

OVERALL CLASS PERFORMANCE (16479 / 17126) = 96.2%　Kappa Statistic (X100) = 95.0%, Kappa Variance = 0.000004.

\+ (100 - percent omission error); also called producer's accuracy.
* (100 - percent commission error); also called user's accuracy.

Table 6　WorldView2（鶴岡，2014.06.29）での土地被覆分類における特徴抽出

バタチャリア (Bhattacharyya)距離

(A) Minimun class distance

	Channels					Min.
1.	3	5	6	7	8	0.71
2.	2	3	5	6	8	0.71
3.	3	4	5	6	8	0.70
4.	1	3	5	6	8	0.70
5.	2	4	5	6	8	0.68
6.	3	4	6	7	8	0.68
7.	2	3	4	6	8	0.68
8.	1	3	4	6	8	0.68
9.	1	4	5	6	8	0.68
10.	1	2	5	6	8	0.67

(B) Average class distance

	Channels					Ave.
1.	3	4	5	6	8	32.83
2.	1	3	5	6	8	32.63
3.	2	3	5	6	8	32.40
4.	3	5	6	7	8	32.34
5.	3	4	5	6	7	32.32
6.	1	3	5	6	7	32.12
7.	2	3	5	6	7	31.90
8.	2	4	5	6	8	31.88
9.	1	3	4	5	6	31.83
10.	4	5	6	7	8	31.80

	Channels						Min.
1.	2	3	5	6	7	8	0.73
2.	2	3	4	5	6	8	0.73
3.	1	3	5	6	7	8	0.73
4.	1	2	3	5	6	8	0.72
5.	3	4	5	6	7	8	0.72
6.	1	3	4	5	6	8	0.72
7.	1	2	4	5	6	8	0.70
8.	1	3	4	6	7	8	0.69
9.	2	4	5	6	7	8	0.69
10.	1	2	3	4	6	8	0.69

	Channels						Ave.
1.	3	4	5	6	7	8	33.23
2.	1	3	4	5	6	8	33.19
3.	2	3	4	5	6	8	33.19
4.	1	3	5	6	7	8	33.00
5.	2	3	5	6	7	8	32.81
6.	1	2	3	5	6	8	32.80
7.	1	3	4	5	6	7	32.73
8.	2	3	4	5	6	7	32.68
9.	2	4	5	6	7	8	32.37
10.	1	2	3	5	6	7	32.26

Fig.10　WorldView2（鶴岡、2013.06.29）とTraining Fields（2回目）(R:Red, G:NIR1, B:Blue)

Table7　WorldView2（鶴岡，2014.06.29）での使用バンドによる農地分類の判別効率変化

Bands used:　1:Coastal, 2:Blue, 3:Green, 4:Yellow, 5:Red, 6:Red edge, 7:NIR1, 8:NIR2
Classes used:　1: rice1　2: rice2　3: soybean1　4: soybean2

(A) 2:Blue, 3:Green, 5:Red, 7:NIR1
TRAINING CLASS PERFORMANCE (Resubstitution Method)　Channels used: 2-3,5,7

Project Class Name	Class Number	Reference Accuracy+ (%)	Number Samples	Number of Samples in Class 1 rice1	2 rice2	3 soybean1	4 soybean2
rice1	1	66.1	11105	7335	3770	0	0
rice2	2	87.0	7243	945	6298	0	0
soybean1	3	94.9	3200	0	0	3038	162
soybean2	4	98.1	5852	0	0	110	5742
TOTAL			27400	8280	10068	3148	5904
Reliability Accuracy (%)*				88.6	62.6	96.5	97.3

OVERALL CLASS PERFORMANCE (22413 / 27400) = 81.8%　Kappa Statistic (X100) = 74.8%. Kappa Variance = 0.000011.

(B) 1:Coastal, 2:Blue, 3:Green, 4:Yellow, 5:Red, 6:Red edge, 7:NIR1, 8:NIR2
TRAINING CLASS PERFORMANCE (Resubstitution Method)　Channels used: 1-8

Project Class Name	Class Number	Reference Accuracy+ (%)	Number Samples	Number of Samples in Class 1 rice1	2 rice2	3 soybean1	4 soybean2
rice1	1	75.7	11105	8406	2699	0	0
rice2	2	90.8	7243	666	6577	0	0
soybean1	3	96.6	3200	0	0	3092	108
soybean2	4	99.4	5852	0	0	34	5818
TOTAL			27400	9072	9276	3126	5926
Reliability Accuracy (%)*				92.7	70.9	98.9	98.2

OVERALL CLASS PERFORMANCE (23893 / 27400) = 87.2%　Kappa Statistic (X100) = 82.1%. Kappa Variance = 0.000008.

(E) (A) + 6:Red edge
TRAINING CLASS PERFORMANCE (Resubstitution Method)　Channels used: 2-3,5-7

Project Class Name	Class Number	Reference Accuracy+ (%)	Number Samples	Number of Samples in Class 1 rice1	2 rice2	3 soybean1	4 soybean2
rice1	1	73.2	11105	8127	2978	0	0
rice2	2	89.0	7243	794	6449	0	0
soybean1	3	95.4	3200	0	0	3052	148
soybean2	4	98.9	5852	0	0	66	5786
TOTAL			27400	8921	9427	3118	5934
Reliability Accuracy (%)*				91.1	68.4	97.9	97.5

OVERALL CLASS PERFORMANCE (23414 / 27400) = 85.5%　Kappa Statistic (X100) = 79.7%. Kappa Variance = 0.000009.

Table 8　WorldView2（鶴岡，2014.06.29）での農地分類における特徴抽出

バタチャリア (Bhattacharyya)距離

(A) Minimun class distance

	Channels					Min.
1.	3	5	6	7	8	0.71
2.	2	3	5	6	8	0.71
3.	3	4	5	6	8	0.70
4.	1	3	5	6	8	0.70
5.	2	4	5	6	8	0.68
6.	3	4	6	7	8	0.68
7.	2	3	4	6	8	0.68
8.	1	3	4	6	8	0.68
9.	1	4	5	6	8	0.68
10.	1	2	5	6	8	0.67

(B) Average class distance

	Channels					Ave.
1.	3	4	5	6	8	32.83
2.	1	3	5	6	8	32.63
3.	2	3	5	6	8	32.40
4.	3	5	6	7	8	32.34
5.	3	4	5	6	7	32.32
6.	1	3	5	6	7	32.12
7.	2	3	5	6	7	31.90
8.	2	4	5	6	8	31.88
9.	1	3	4	5	6	31.83
10.	4	5	6	7	8	31.80

	Channels						Min.
1.	2	3	5	6	7	8	0.73
2.	2	3	4	5	6	8	0.73
3.	1	3	5	6	7	8	0.73
4.	1	2	3	5	6	8	0.72
5.	3	4	5	6	7	8	0.72
6.	1	3	4	5	6	8	0.72
7.	1	2	4	5	6	8	0.70
8.	1	3	4	6	7	8	0.69
9.	2	4	5	6	7	8	0.69
10.	1	2	3	4	6	8	0.69

	Channels						Ave.
1.	3	4	5	6	7	8	33.23
2.	1	3	4	5	6	8	33.19
3.	2	3	4	5	6	8	33.19
4.	1	3	5	6	7	8	33.00
5.	2	3	5	6	7	8	32.81
6.	1	2	3	5	6	8	32.80
7.	1	3	4	5	6	7	32.73
8.	2	3	4	5	6	7	32.68
9.	2	4	5	6	7	8	32.37
10.	1	2	3	5	6	7	32.26

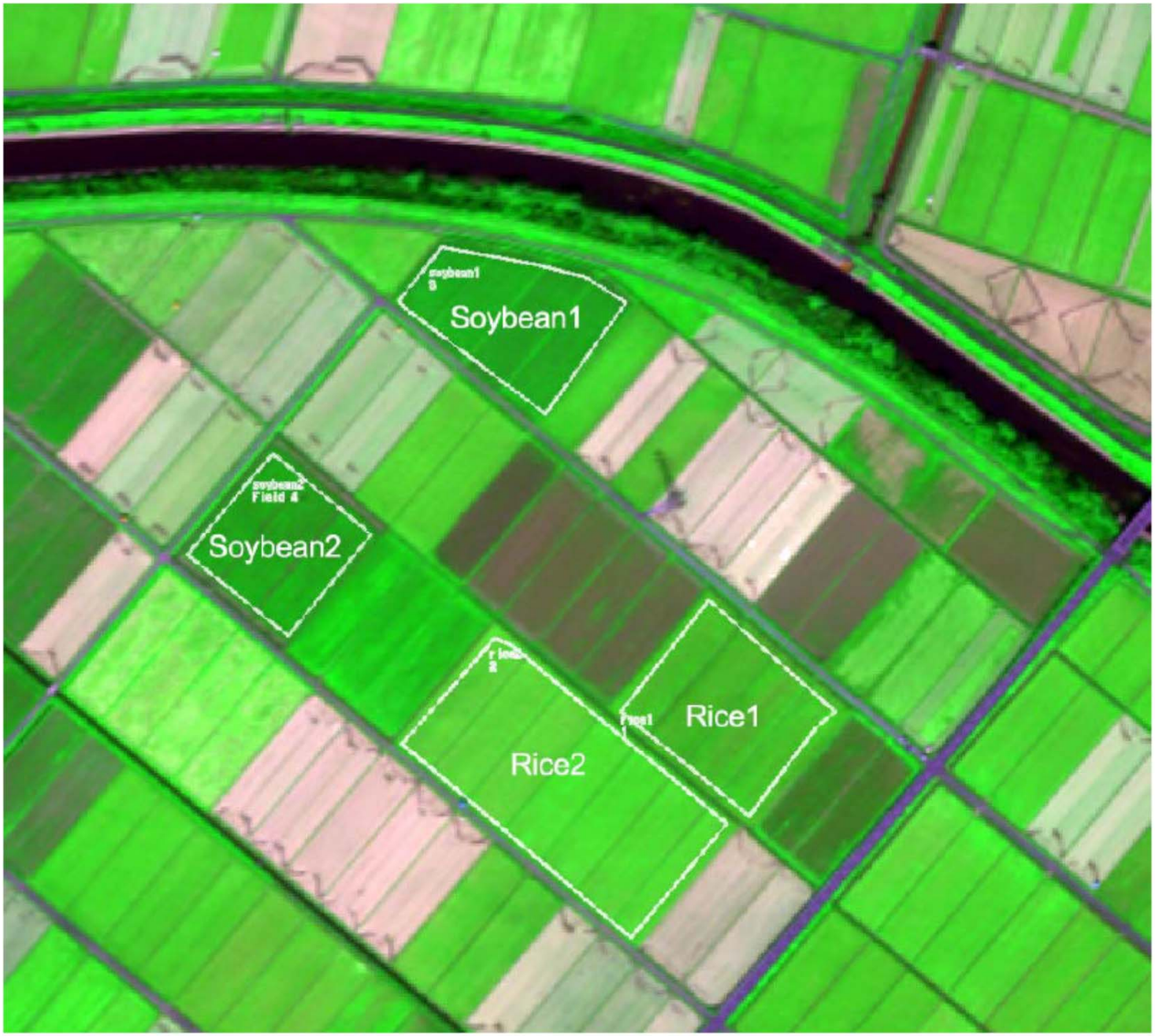


Fig.11　WorldView2（鶴岡、2014.09.24）とTraining Fields　（R:Red, G:NIR1, B:Blue）

Table 9　WorldView2（鶴岡，2014.09.24）での使用バンドによる農地分類の判別効率変化

Bands used: 1:Coastal, 2:Blue, 3:Green, 4:Yellow, 5:Red, 6:Red edge, 7:NIR1, 8:NIR2
Classes used: 1: rice1 2: rice2 3: soybean1 4: soybean2

(A) 2:Blue, 3:Green, 5:Red, 7:NIR1
TRAINING CLASS PERFORMANCE (Resubstitution Method) Channels used: 2-3,5,7

Project Class Name	Class Number	Reference Accuracy+ (%)	Number Samples	Number of Samples in Class 1 rice1	2 rice2	3 soybean1	4 soybean2
rice1	1	99.0	3606	3571	35	0	0
rice2	2	97.3	6935	186	6749	0	0
soybean1	3	81.8	3200	8	0	2616	576
soybean2	4	75.2	2663	2	0	659	2002
TOTAL			16404	3767	6784	3275	2578
Reliability Accuracy (%)*				94.8	99.5	79.9	77.7

OVERALL CLASS PERFORMANCE (14938 / 16404) = 91.1%　Kappa Statistic (X100) = 87.4%. Kappa Variance = 0.000009.

(B) 1:Coastal, 2:Blue, 3:Green, 4:Yellow, 5:Red, 6:Red edge, 7:NIR1, 8:NIR2
TRAINING CLASS PERFORMANCE (Resubstitution Method) Channels used: 1-8

Project Class Name	Class Number	Reference Accuracy+ (%)	Number Samples	Number of Samples in Class 1 rice1	2 rice2	3 soybean1	4 soybean2
rice1	1	99.8	3606	3598	8	0	0
rice2	2	99.0	6935	68	6867	0	0
soybean1	3	95.5	3200	8	0	3056	136
soybean2	4	96.7	2663	1	0	88	2574
TOTAL			16404	3675	6875	3144	2710
Reliability Accuracy (%)*				97.9	99.9	97.2	95.0

OVERALL CLASS PERFORMANCE (16095 / 16404) = 98.1%　Kappa Statistic (X100) = 97.3%. Kappa Variance = 0.000002.

(E) (A) + 6:Red edge
TRAINING CLASS PERFORMANCE (Resubstitution Method) Channels used: 2-3,5-7

Project Class Name	Class Number	Reference Accuracy+ (%)	Number Samples	Number of Samples in Class 1 rice1	2 rice2	3 soybean1	4 soybean2
rice1	1	99.5	3606	3589	17	0	0
rice2	2	98.9	6935	75	6860	0	0
soybean1	3	94.1	3200	10	0	3011	179
soybean2	4	94.0	2663	2	0	157	2504
TOTAL			16404	3676	6877	3168	2683
Reliability Accuracy (%)*				97.6	99.8	95.0	93.3

OVERALL CLASS PERFORMANCE (15964 / 16404) = 97.3%　Kappa Statistic (X100) = 96.2%. Kappa Variance = 0.000003.

Table 10　WorldView2（鶴岡，2014.09.24）での農地分類における特徴抽出

(A) Minimun class distance

	Channels					Min.
1.	3	5	6	7	8	0.71
2.	2	3	5	6	8	0.71
3.	3	4	5	6	8	0.70
4.	1	3	5	6	8	0.70
5.	2	4	5	6	8	0.68
6.	3	4	6	7	8	0.68
7.	2	3	4	6	8	0.68
8.	1	3	4	6	8	0.68
9.	1	4	5	6	8	0.68
10.	1	2	5	6	8	0.67

(B) Average class distance

	Channels					Ave.
1.	3	4	5	6	8	32.83
2.	1	3	5	6	8	32.63
3.	2	3	5	6	8	32.40
4.	3	5	6	7	8	32.34
5.	3	4	5	6	7	32.32
6.	1	3	5	6	7	32.12
7.	2	3	5	6	7	31.90
8.	2	4	5	6	8	31.88
9.	1	3	4	5	6	31.83
10.	4	5	6	7	8	31.80

	Channels						Min.
1.	2	3	5	6	7	8	0.73
2.	2	3	4	5	6	8	0.73
3.	1	3	5	6	7	8	0.73
4.	1	2	3	5	6	8	0.72
5.	3	4	5	6	7	8	0.72
6.	1	3	4	5	6	8	0.72
7.	1	2	4	5	6	8	0.70
8.	1	3	4	6	7	8	0.69
9.	2	4	5	6	7	8	0.69
10.	1	2	3	4	6	8	0.69

	Channels						Ave.
1.	3	4	5	6	7	8	33.23
2.	1	3	4	5	6	8	33.19
3.	2	3	4	5	6	8	33.19
4.	1	3	5	6	7	8	33.00
5.	2	3	5	6	7	8	32.81
6.	1	2	3	5	6	8	32.80
7.	1	3	4	5	6	7	32.73
8.	2	3	4	5	6	7	32.68
9.	2	4	5	6	7	8	32.37
10.	1	2	3	5	6	7	32.26

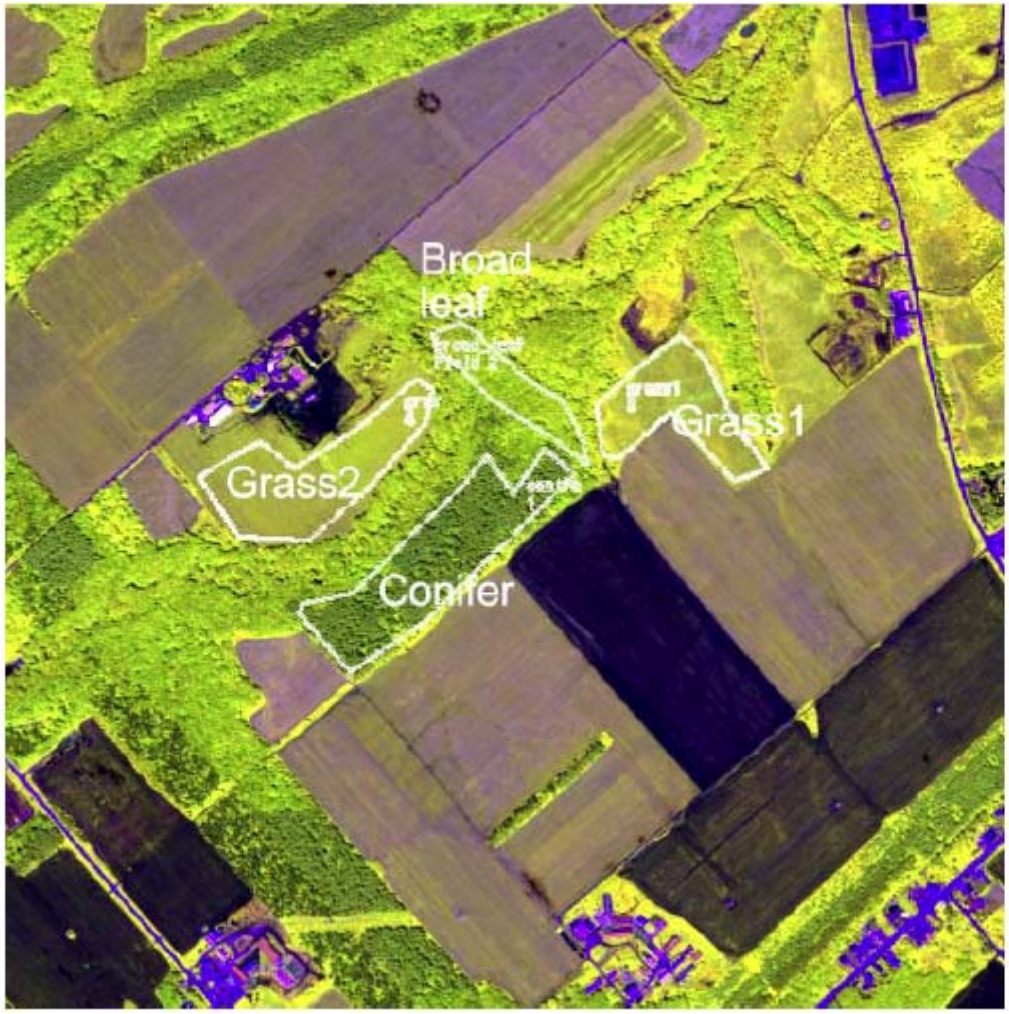


Fig.12　WorldView2（中標津、2014.07.12）と Training Fields（R:Red_edge, G:NIR2, B:Coastal）

Table 11　WorldView2（中標津，2014.07.12）での使用バンドによる植生分類の判別効率変化

Bands used: 1:Coastal, 2:Blue, 3:Green, 4:Yellow, 5:Red, 6:Red edge, 7:NIR1, 8:NIR2
Classes used: 1: conifer 2: broad_leaf 3: grass1 4: grass2

(A) 2:Blue, 3:Green, 5:Red, 7:NIR1
TRAINING CLASS PERFORMANCE (Resubstitution Method) Channels used: 2-3,5,7

Project Class Name	Class Number	Reference Accuracy (%)	Number Samples	Number of Samples in Class 1 conifer	2 broad_leaf	3 grass1	4 grass2
conifer	1	93.1	23895	22244	1483	138	30
broad_leaf	2	94.2	7820	412	7368	32	8
grass1	3	72.2	13523	100	254	9757	3412
grass2	4	92.7	19196	50	38	1314	17794
TOTAL			64434	22806	9143	11241	21244
Reliability Accuracy (%)				97.5	80.6	86.8	83.8

OVERALL CLASS PERFORMANCE (57163 / 64434) = 88.7% Kappa Statistic (X100) = 84.3%. Kappa Variance = 0.000003

(B) 1:Coastal, 2:Blue, 3:Green, 4:Yellow, 5:Red, 6:Red edge, 7:NIR1, 8:NIR2
TRAINING CLASS PERFORMANCE (Resubstitution Method) Channels used: 1-8

Project Class Name	Class Number	Reference Accuracy (%)	Number Samples	Number of Samples in Class 1 conifer	2 broad_leaf	3 grass1	4 grass2
conifer	1	93.0	23895	22214	1564	105	12
broad_leaf	2	95.8	7820	304	7492	23	1
grass1	3	80.9	13523	79	277	10944	2223
grass2	4	95.2	19196	69	3	843	18281
TOTAL			64434	22666	9336	11915	20517
Reliability Accuracy (%)				98.0	80.2	91.9	89.1

OVERALL CLASS PERFORMANCE (58931 / 64434) = 91.5% Kappa Statistic (X100) = 88.1%. Kappa Variance = 0.000002.

(E) (A) + 6:Red edge
TRAINING CLASS PERFORMANCE (Resubstitution Method) Channels used: 2-3,5-7

Project Class Name	Class Number	Reference Accuracy (%)	Number Samples	Number of Samples in Class 1 conifer	2 broad_leaf	3 grass1	4 grass2
conifer	1	93.0	23895	22218	1527	126	24
broad_leaf	2	95.0	7820	350	7427	41	2
grass1	3	76.9	13523	130	265	10405	2723
grass2	4	94.6	19196	63	10	961	18162
TOTAL			64434	22761	9229	11533	20911
Reliability Accuracy (%)				97.6	80.5	90.2	86.9

OVERALL CLASS PERFORMANCE (58212 / 64434) = 90.3% Kappa Statistic (X100) = 86.5%. Kappa Variance = 0.000003.

Table 12　WorldView2（中標津，2014.07.12）での植生分類における特徴抽出

バタチャリア (Bhattacharyya)距離

(A) Minimun class distance

	Channels					Min.
1.	3	5	6	7	8	0.82
2.	1	3	5	6	8	0.80
3.	2	3	5	6	8	0.79
4.	2	3	5	6	7	0.76
5.	1	3	5	6	7	0.76
6.	3	4	5	6	8	0.73
7.	3	4	5	6	7	0.71
8.	1	2	3	5	6	0.70
9.	1	3	4	5	6	0.68
10.	2	3	4	6	8	0.67

(B) Average class distance

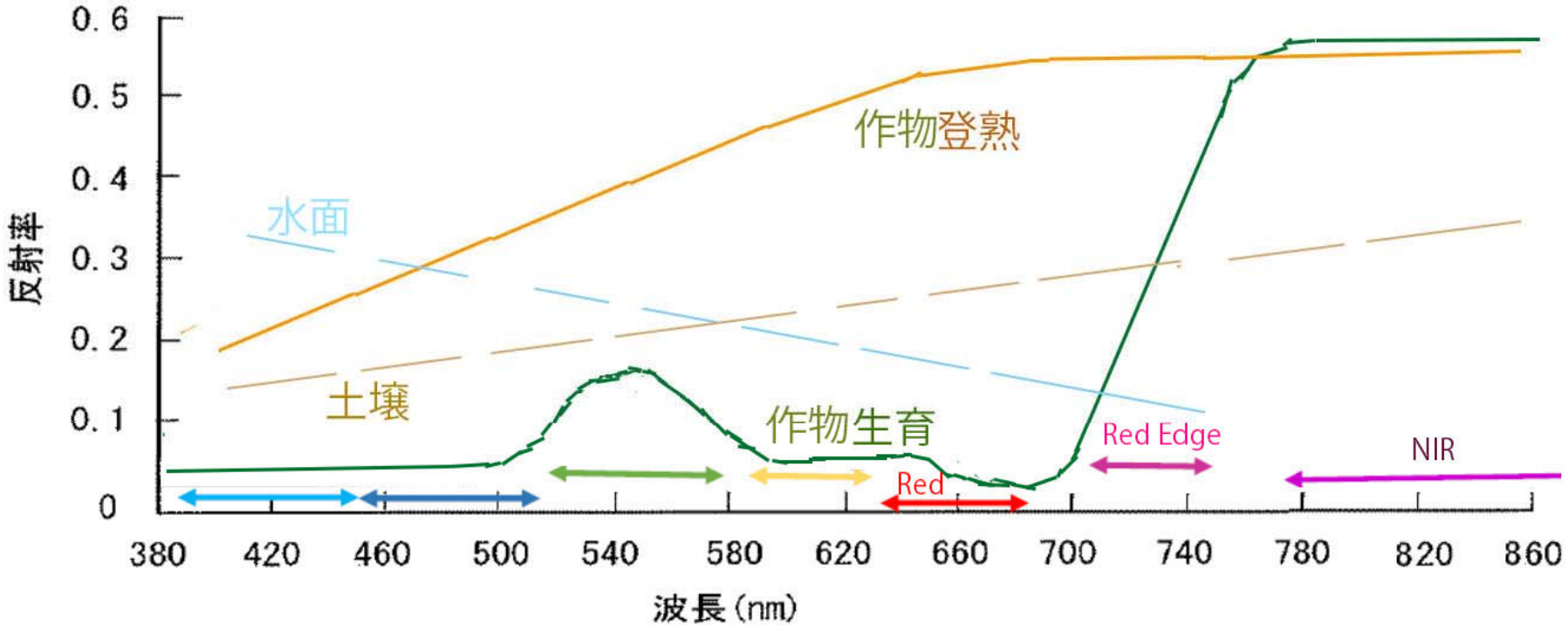
	Channels					Ave.
1.	1	3	5	6	7	3.85
2.	2	3	5	6	7	3.85
3.	2	3	5	6	8	3.83
4.	1	2	3	5	6	3.83
5.	1	3	5	6	8	3.81
6.	2	3	4	5	6	3.78
7.	1	3	4	5	6	3.78
8.	3	5	6	7	8	3.76
9.	2	3	5	7	8	3.68
10.	1	3	5	7	8	3.66

	Channels						Min.
1.	1	3	5	6	7	8	0.89
2.	2	3	5	6	7	8	0.89
3.	1	2	3	5	6	8	0.84
4.	3	4	5	6	7	8	0.83
5.	1	3	4	5	6	8	0.80
6.	1	2	3	5	6	7	0.80
7.	2	3	4	5	6	8	0.79
8.	2	3	4	5	6	7	0.77
9.	1	3	4	5	6	7	0.77
10.	2	3	4	6	7	8	0.75

	Channels						Ave.
1.	1	3	5	6	7	8	4.08
2.	2	3	5	6	7	8	4.08
3.	1	2	3	5	6	7	4.02
4.	1	2	3	5	6	8	3.99
5.	1	2	3	4	5	6	3.96
6.	2	3	4	5	6	8	3.95
7.	1	3	4	5	6	7	3.95
8.	1	3	4	5	6	8	3.94
9.	2	3	4	5	6	7	3.94
10.	1	2	3	5	7	8	3.85

5. Red Edgeの利用例

Red edge 指数＝（Red edge – Red）/ （NIR – Red） ---------- （式 1）



Coastal:	400 - 450 nm	Red:	630 - 690 nm
Blue:	450 - 510 nm	Red Edge:	705 - 745 nm
Green:	510 - 580 nm	Near-IR1:	770 - 895 nm
Yellow:	585 - 625 nm	Near-IR2:	860 - 1040 nm

Fig. 14　緑葉と枯葉のスペクトル特性と WorldView2 のバンドの関係

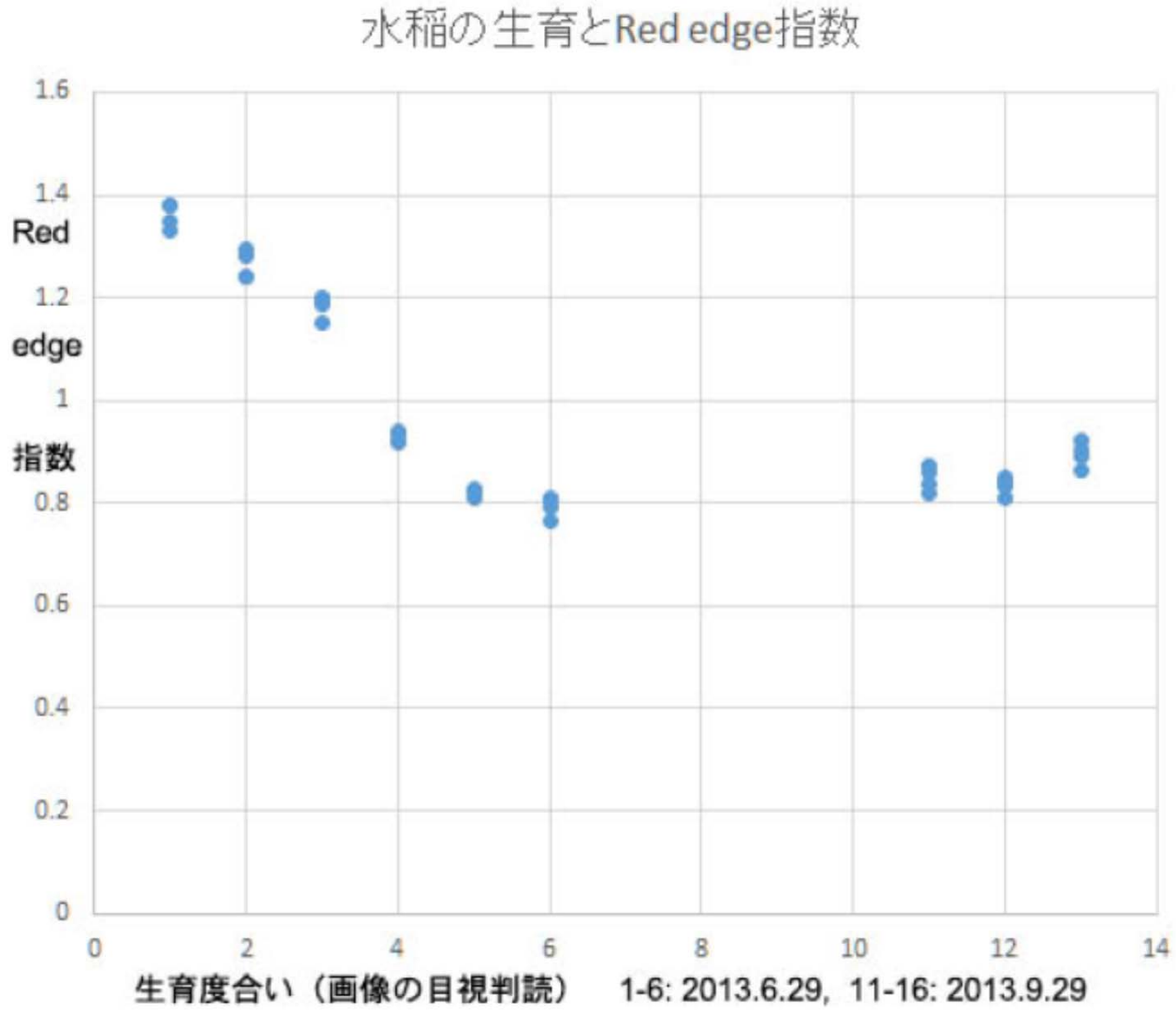


Fig. 15　WorldView2 の Red edge 指数（仮称）と水稲生育度合いの関係

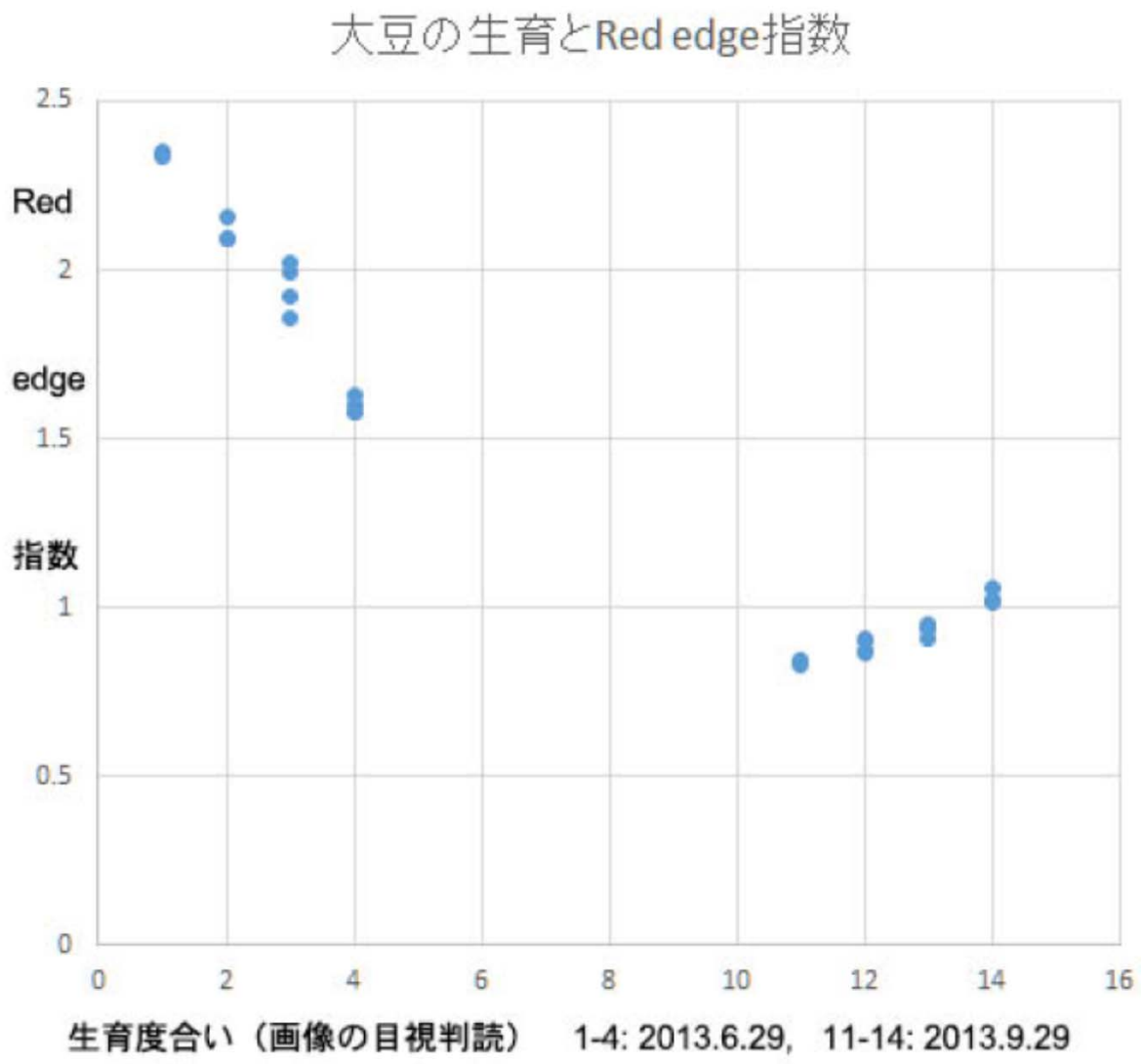
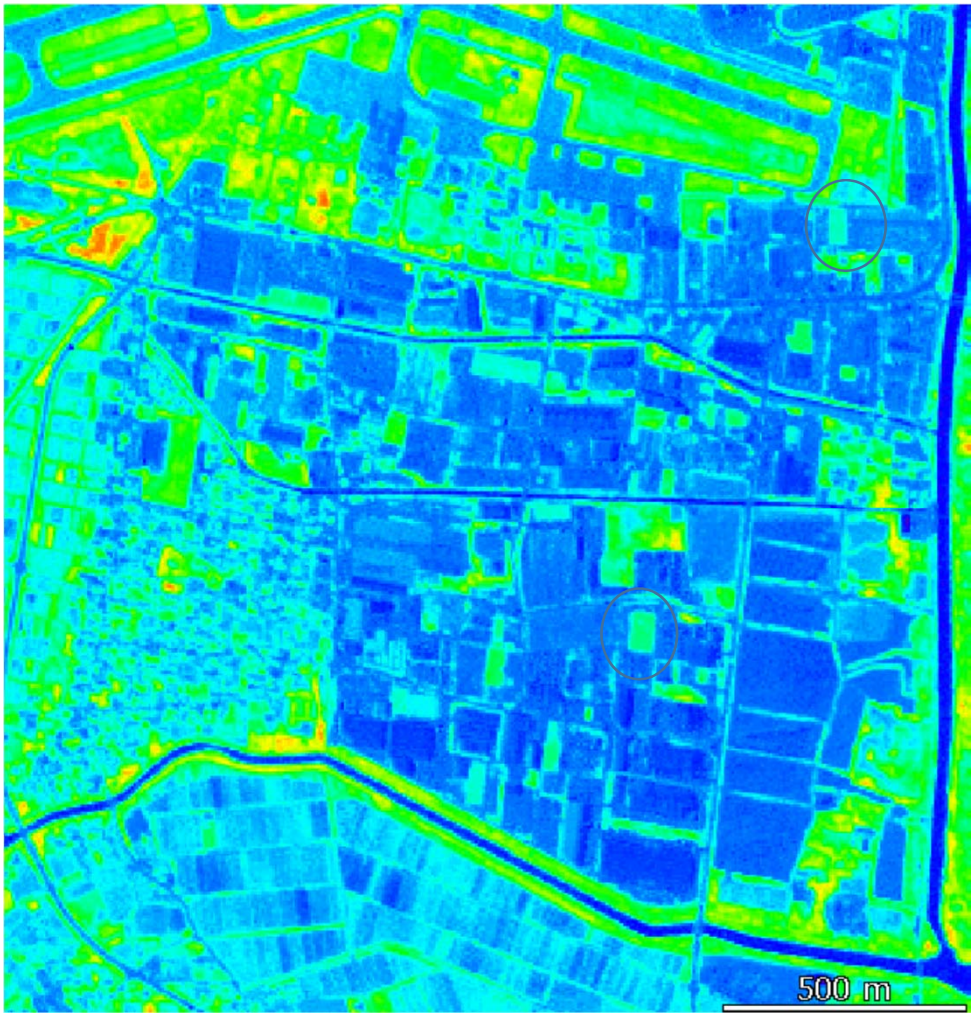


Fig. 16　WorldView2 の Red edge 指数（仮称）と大豆生育度合いの関係

NIRバンド利用とRed Edgeバンド利用のNDVIの違い

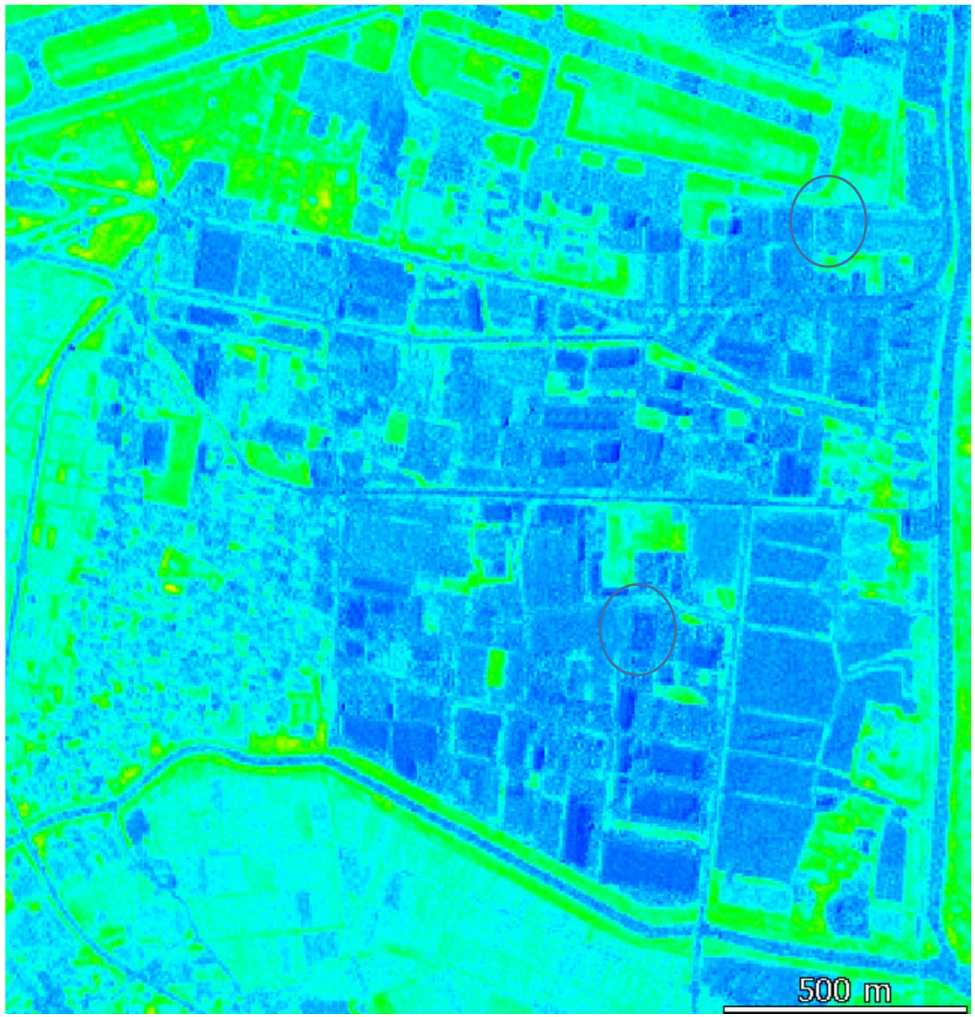


RE_20140531
NDVI

単に青い屋根の
建物で擬似的に
NDVIが高いだけ

NDVIだけで判断
すると間違うが、
レッドエッジの
NDVIなら大丈夫

RE_20140531
RGB=RGB



RE_20140531
NDVI_Rededge

6. 結論（未定稿）

植生分類で、WorldView2バンドでは

Band6（Red Edge)

> Band8 (NIR2)

> Band1 (Coastal)

> Band4 (Yellow)

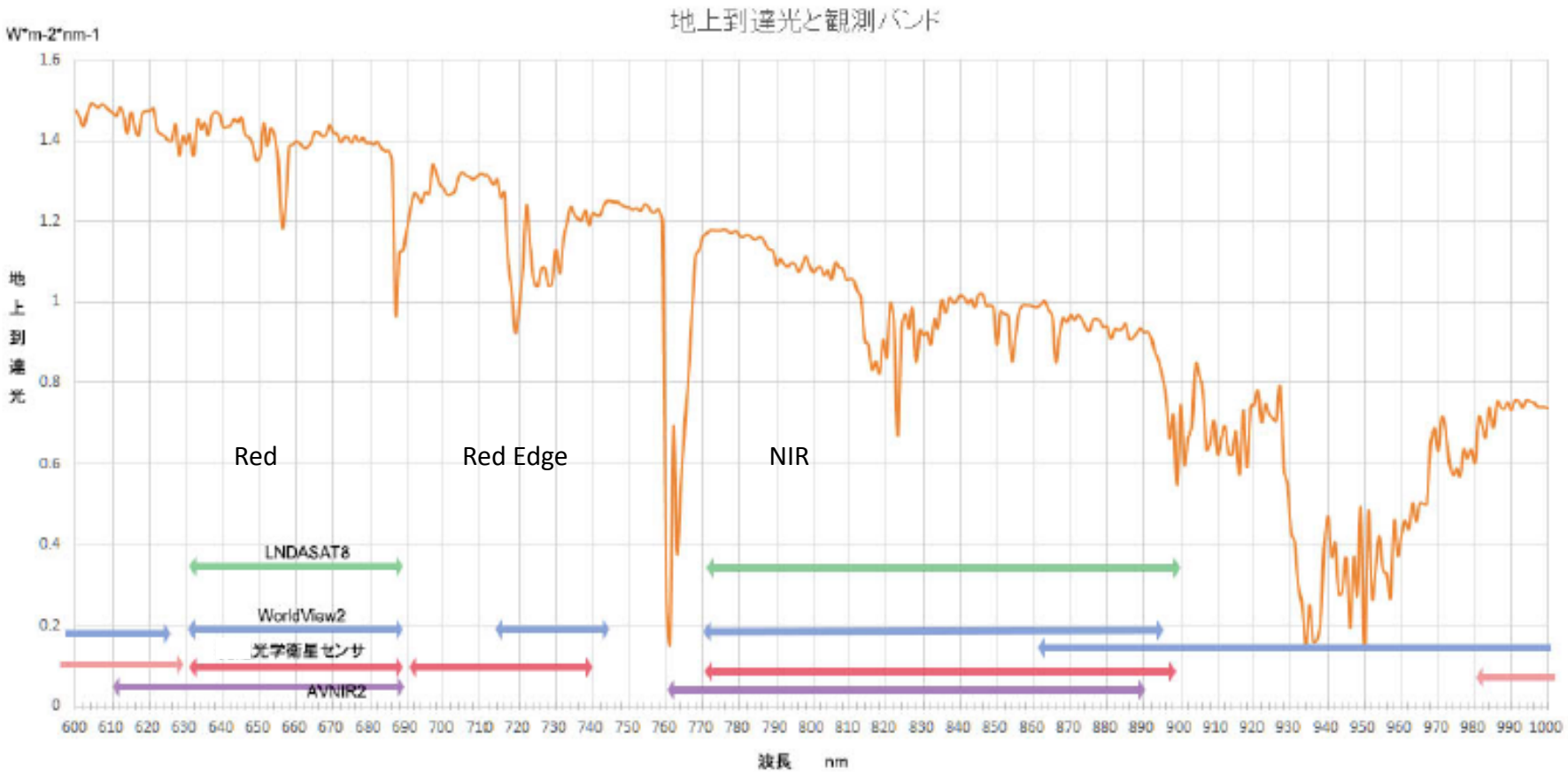


Fig. 17　赤～近赤外域の地上到達光量と各種光学衛星センサのバンド帯

CORRELATION MATRIX　鶴岡北部　2014.06.29

Layer	1. Coastal	2. Blue	3. Green	4. Yellow	5. Red	6. Red Edge	7. NIR1	8. NIR2
1	1.00000	0.98748	0.96426	0.95514	0.94078	0.51030	-0.01591	0.06413
2	0.98748	1.00000	0.98115	0.96950	0.96535	0.52128	-0.01558	0.06831
3	0.96426	0.98115	1.00000	0.97901	0.97209	0.63257	0.10180	0.18126
4	0.95514	0.96950	0.97901	1.00000	0.99299	0.53949	-0.02181	0.06323
5	0.94078	0.96535	0.97209	0.99299	1.00000	0.50679	-0.05554	0.03217
6	0.51030	0.52128	0.63257	0.53949	0.50679	1.00000	0.81031	0.85004
7	-0.01591	-0.01558	0.10180	-0.02181	-0.05554	0.81031	1.00000	0.98082
8	0.06413	0.06831	0.18126	0.06323	0.03217	0.85004	0.98082	1.00000

Table 4　WorldView2　　鶴岡北部エリア（2014.09.13）についての各バンド間相関

Layer	1. Coastal	2. Blue	3. Green	4. Yellow	5. Red	6. Red Edge	7. NIR1	8. NIR2
1	1.00000	0.93377	0.73819	0.71041	0.73246	0.19798	0.00904	0.03953
2	0.93377	1.00000	0.87792	0.87742	0.91038	0.36037	0.14488	0.18794
3	0.73819	0.87792	1.00000	0.97724	0.92858	0.73144	0.53037	0.55923
4	0.71041	0.87742	0.97724	1.00000	0.97339	0.68616	0.46422	0.50573
5	0.73246	0.91038	0.92858	0.97339	1.00000	0.55360	0.32883	0.38033
6	0.19798	0.36037	0.73144	0.68616	0.55360	1.00000	0.95065	0.95646
7	0.00904	0.14488	0.53037	0.46422	0.32883	0.95065	1.00000	0.99203
8	0.03953	0.18794	0.55923	0.50573	0.38033	0.95646	0.99203	1.00000

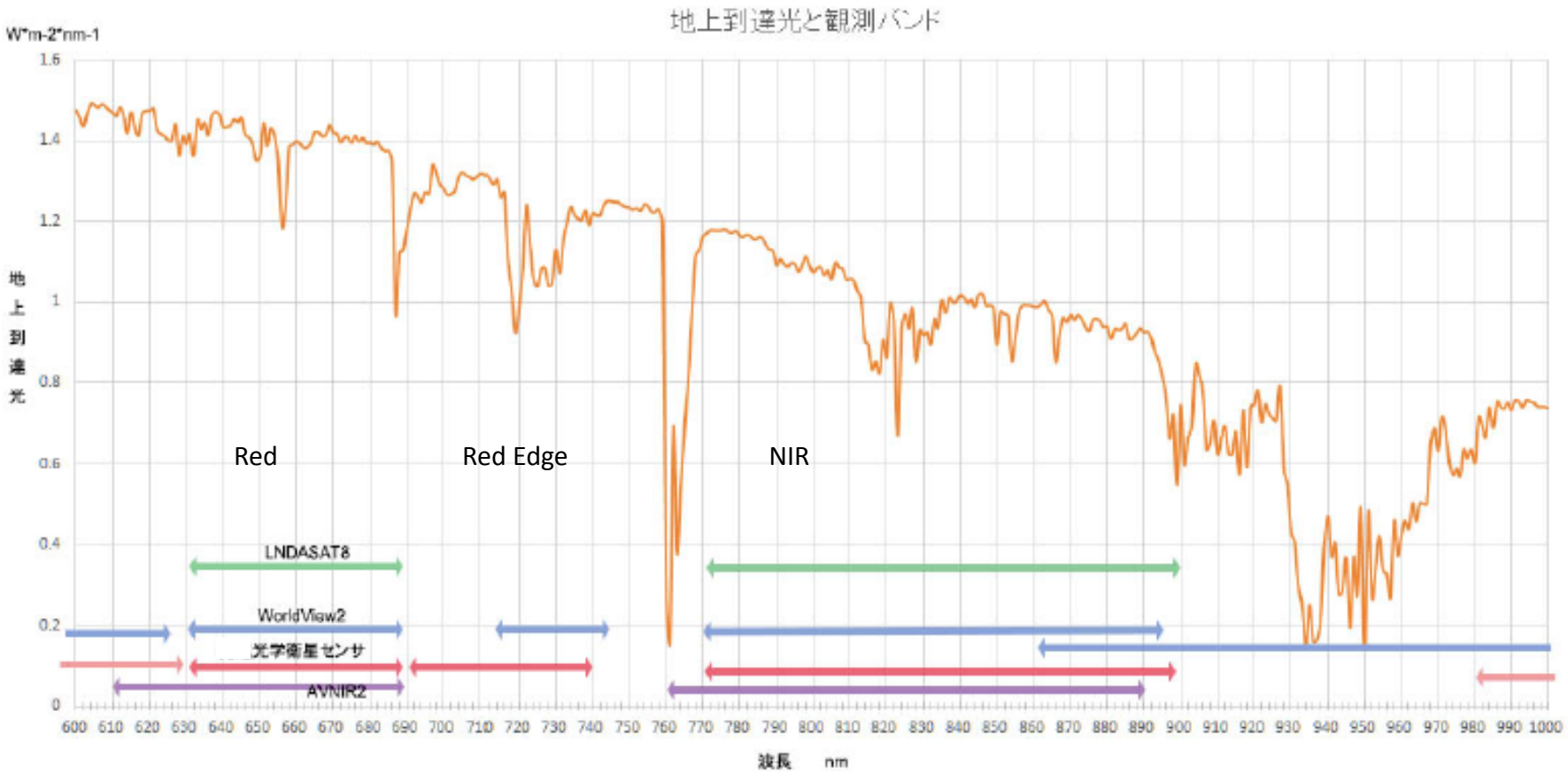


Fig. 17　赤～近赤外域の地上到達光量と各種光学衛星センサのバンド帯

ご静聴ありがとうございました。