All you need to know about spectral/spatial alignment impact on derived-parameter uncertainty *in 10 minutes*

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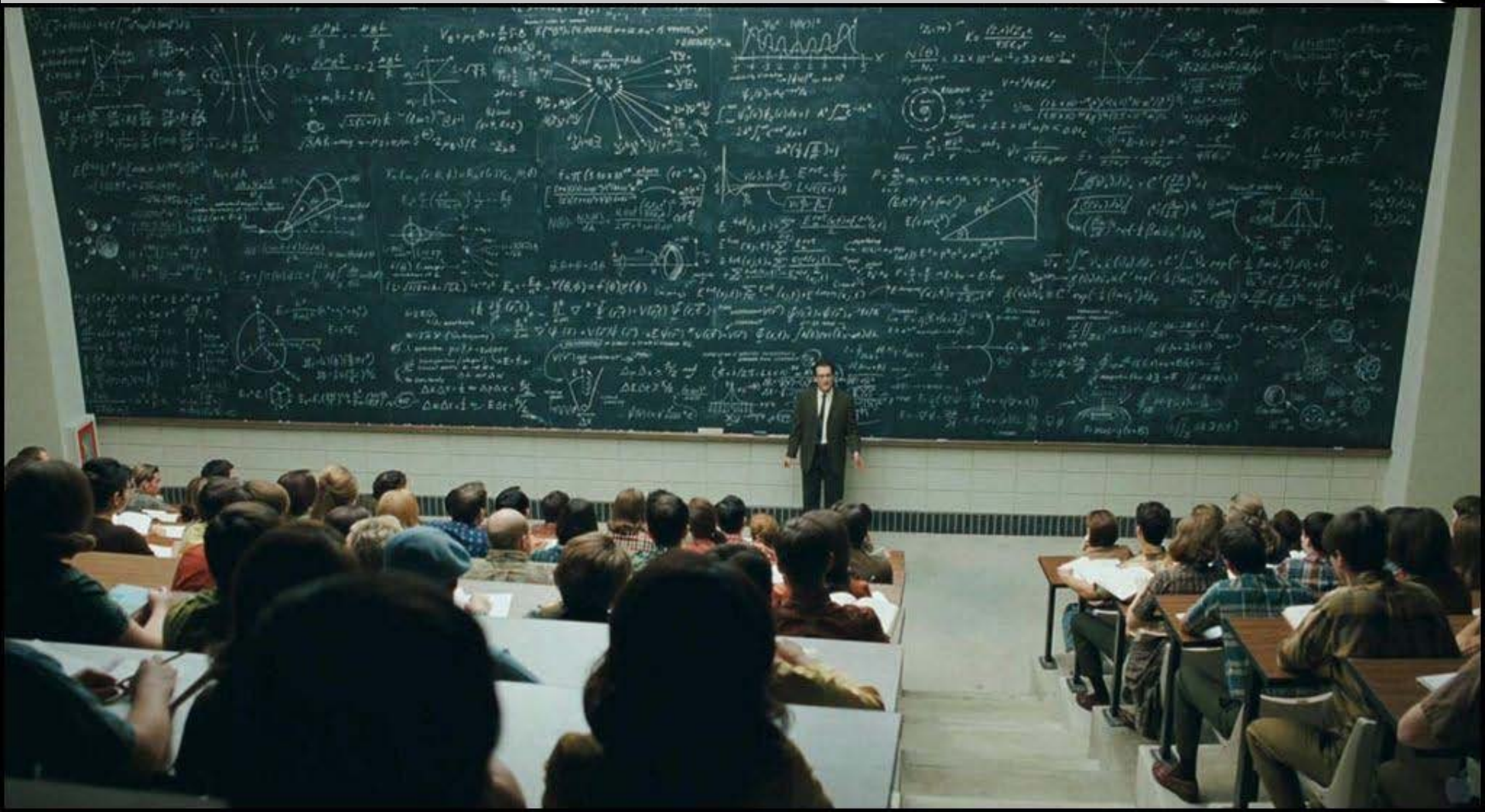
HyspIRI Science Symposium – NASA GSFC – May 4, 2010



Spectral/Spatial Alignment Impact

Multi-Spectral

Band-to-band misalignment limits parameter estimation accuracies at pixel, regional and global scales *which cannot be "corrected" by re-sampling (e.g. Bilinear interpolation).*

Even perfectly aligned observing systems provide pixel and regional scale measurements sensitive to spatial sampling *which cannot be adequately "adjusted" through re-sampling.*

Spectral/Spatial Alignment Impact

Why is this important?

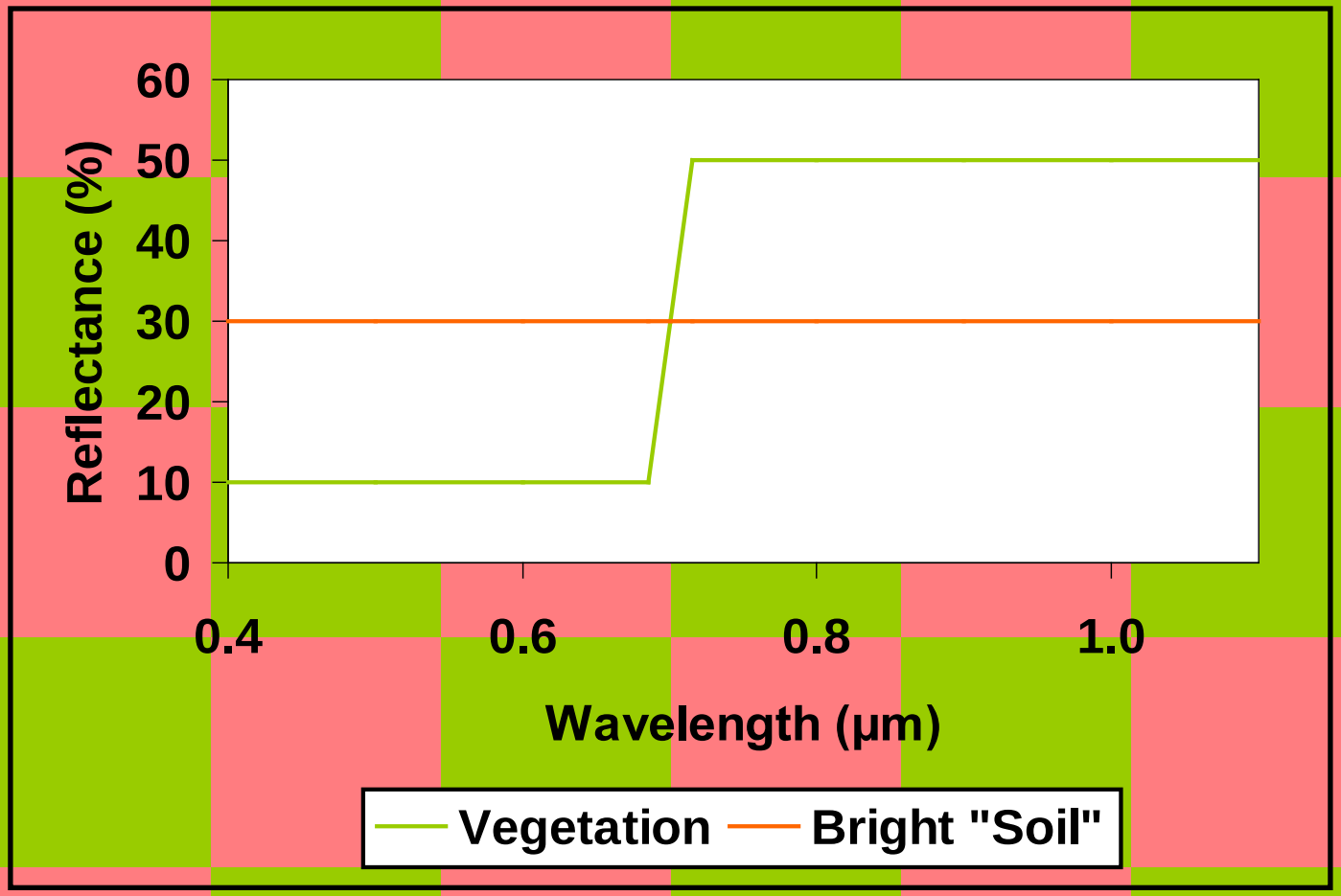
Biophysical parameters are derived by using combinations of spectral band reflectance values (e.g. band ratios) at the pixel level.

Continuously Spectral

Properly designed imaging spectrometers possess Inherent spectral/spatial integrity.

Spectral content can be used to mitigate the impact of temporal sampling offsets.

Synthetic Scene Composition



Landscape Reflectance Values
Synthetic Scene Scenario

.3	.1	.3	.1
.1	.3	.1	.3
.3	.1	.3	.1
.1	.3	.1	.3

VIS Reflectance

.3	.5	.3	.5
.5	.3	.5	.3
.3	.5	.3	.5
.5	.3	.5	.3

NIR Reflectance

Landscape Reflectance Ratios
Synthetic Scene Scenario

NIR Reflectance

.3	.5	.3	.5
.5	.3	.5	.3
.3	.5	.3	.5
.5	.3	.5	.3

VIS Reflectance

.3	.1	.3	.1
.1	.3	.1	.3
.3	.1	.3	.1
.1	.3	.1	.3

=

1	5	1	5
5	1	5	1
1	5	1	5
5	1	5	1

$$\frac{\text{NIR-Reflectance}}{\text{VIS-Reflectance}} = \text{VI}$$

“Scene” Reflectance Ratio
Synthetic Scene Scenario

NIR Reflectance

.3	.5	.3	.5
.5	.3	.5	.3
.3	.5	.3	.5
.5	.3	.5	.3

VIS Reflectance

.3	.1	.3	.1
.1	.3	.1	.3
.3	.1	.3	.1
.1	.3	.1	.3

=

1	5	1	5
5	1	5	1
1	5	1	5
5	1	5	1

3

$$\frac{\text{NIR-Reflectance}}{\text{VIS-Reflectance}} = \text{VI}$$

Ratio of Scene Reflectance Synthetic Scene Scenario

NIR Reflectance

.3	.5	.3	.5
.5	.3	.5	.3
.3	.5	.3	.5
.5	.3	.5	.3

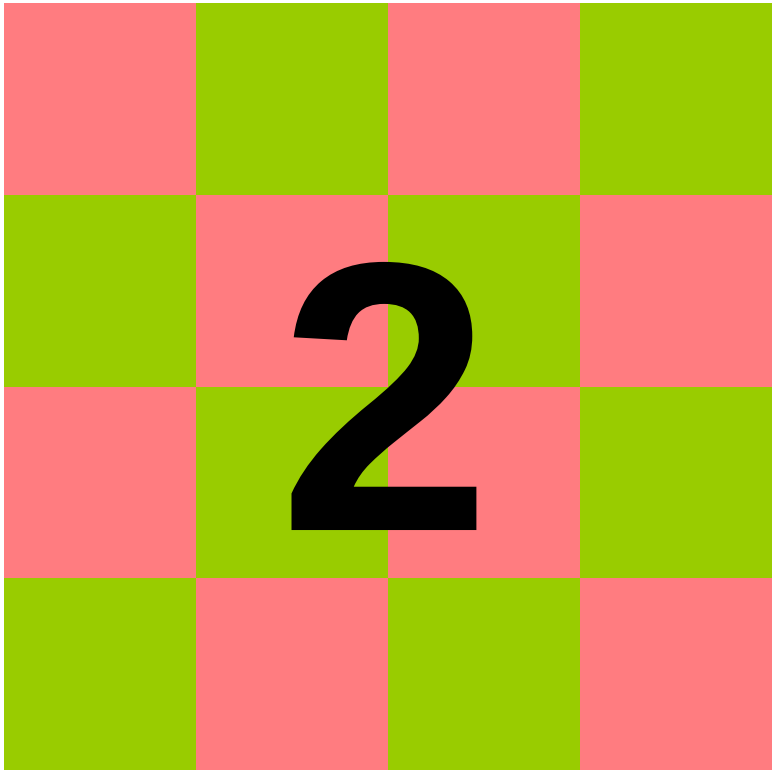
4

VIS Reflectance

.3	.1	.3	.1
.1	.3	.1	.3
.3	.1	.3	.1
.1	.3	.1	.3

2

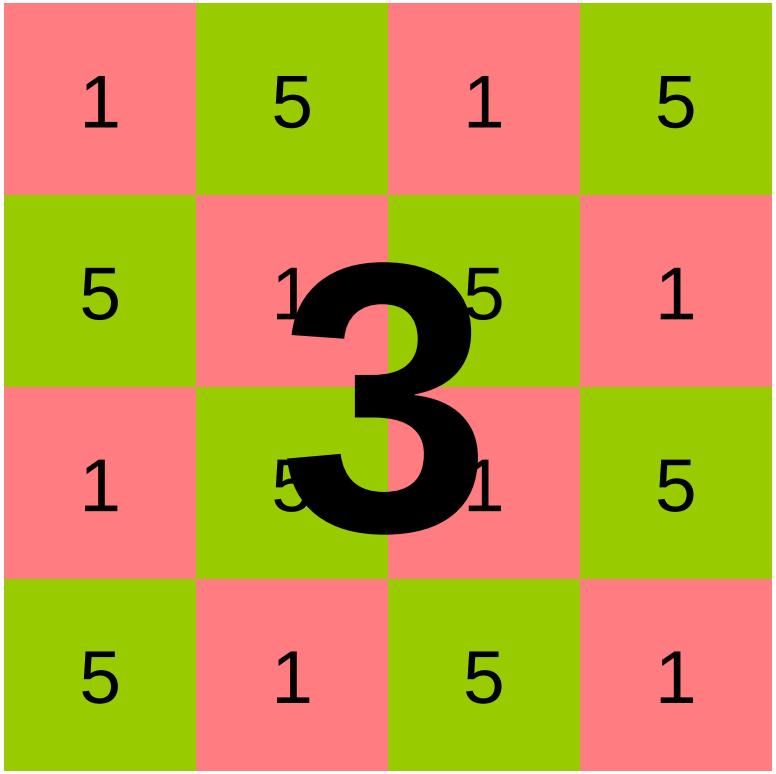
=



$$\frac{\text{NIR-Reflectance}}{\text{VIS-Reflectance}} = \text{VI}$$

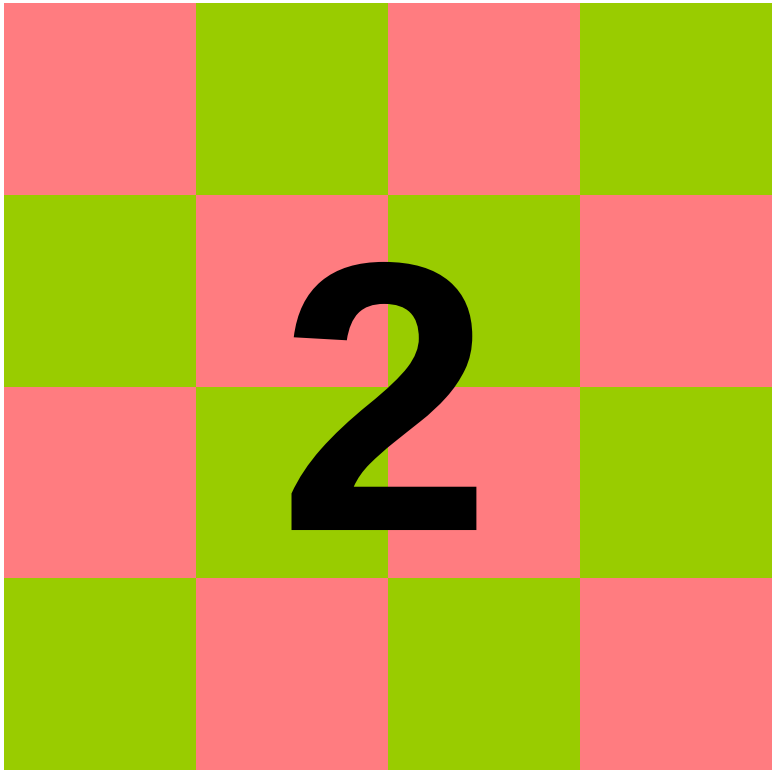
Synthetic Scene Scenario

"Scene" Reflectance-Ratio



$$\left\langle \frac{\text{NIR-Reflectance}}{\text{VIS-Reflectance}} \right\rangle$$

Ratio of Scene Reflectances



$$\frac{\langle \text{NIR-Reflectance} \rangle}{\langle \text{VIS-Reflectance} \rangle}$$

Pixel Reflectance Values
Aligned Bands Scenario

.3	.3	.3	.1	.1	.1	.3	.3	.3	.1	.1	.1
.3	.3	.3	.1	.1	.1	.3	.3	.3	.1	.1	.1
.3	.3	.3	.1	.1	.1	.3	.3	.3	.1	.1	.1
.1	.1	.1	.3	.3	.3	.1	.1	.1	.3	.3	.3
.1	.1	.1	.3	.3	.3	.1	.1	.1	.3	.3	.3
.1	.1	.1	.3	.3	.3	.1	.1	.1	.3	.3	.3
.3	.3	.3	.1	.1	.1	.3	.3	.3	.1	.1	.1
.3	.3	.3	.1	.1	.1	.3	.3	.3	.1	.1	.1
.3	.3	.3	.1	.1	.1	.3	.3	.3	.1	.1	.1
.1	.1	.1	.3	.3	.3	.1	.1	.1	.3	.3	.3
.1	.1	.1	.3	.3	.3	.1	.1	.1	.3	.3	.3
.1	.1	.1	.3	.3	.3	.1	.1	.1	.3	.3	.3

Nominal Position VIS Band

.3	.3	.3	.5	.5	.5	.3	.3	.3	.5	.5	.5
.3	.3	.3	.5	.5	.5	.3	.3	.3	.5	.5	.5
.3	.3	.3	.5	.5	.5	.3	.3	.3	.5	.5	.5
.5	..5	.5	.3	.3	.3	.5	..5	.5	.3	.3	.3
.5	.5	.5	.3	.3	.3	.5	.5	.5	.3	.3	.3
.5	.5	.5	.3	.3	.3	.5	.5	.5	.3	.3	.3
.3	.3	.3	.5	.5	.5	.3	.3	.3	.5	.5	.5
.3	.3	.3	.5	.5	.5	.3	.3	.3	.5	.5	.5
.3	.3	.3	.5	.5	.5	.3	.3	.3	.5	.5	.5
.5	..5	.5	.3	.3	.3	.5	..5	.5	.3	.3	.3
.5	.5	.5	.3	.3	.3	.5	.5	.5	.3	.3	.3
.5	.5	.5	.3	.3	.3	.5	.5	.5	.3	.3	.3

Nominal Position NIR Band

Pixel Reflectance Values
Misaligned Bands Scenario 1

.3	.3	.2	.1	.1	.2	.3	.3	.2	.1	.1	.2
.3	.3	.2	.1	.1	.2	.3	.3	.2	.1	.1	.2
.3	.3	.2	.1	.1	.2	.3	.3	.2	.1	.1	.2
.1	.1	.2	.3	.3	.2	.1	.1	.2	.3	.3	.2
.1	.1	.2	.3	.3	.2	.1	.1	.2	.3	.3	.2
.1	.1	.2	.3	.3	.2	.1	.1	.2	.3	.3	.2
.3	.3	.2	.1	.1	.2	.1	.1	.2	.1	.1	.2
.3	.3	.2	.1	.1	.2	.1	.1	.2	.1	.1	.2
.3	.3	.2	.1	.1	.2	.1	.1	.2	.1	.1	.2
.1	.1	.2	.3	.3	.2	.1	.1	.2	.3	.3	.2
.1	.1	.2	.3	.3	.2	.1	.1	.2	.3	.3	.2
.1	.1	.2	.3	.3	.2	.1	.1	.2	.3	.3	.2

"Half-pixel" Shift VIS Band

.3	.3	.3	.5	.5	.5	.3	.3	.3	.5	.5	.5
.3	.3	.3	.5	.5	.5	.3	.3	.3	.5	.5	.5
.3	.3	.3	.5	.5	.5	.3	.3	.3	.5	.5	.5
.5	..5	.5	.3	.3	.3	.5	..5	.5	.3	.3	.3
.5	.5	.5	.3	.3	.3	.5	.5	.5	.3	.3	.3
.5	.5	.5	.3	.3	.3	.5	.5	.5	.3	.3	.3
.3	.3	.3	.5	.5	.5	.3	.3	.3	.5	.5	.5
.3	.3	.3	.5	.5	.5	.3	.3	.3	.5	.5	.5
.3	.3	.3	.5	.5	.5	.3	.3	.3	.5	.5	.5
.5	..5	.5	.3	.3	.3	.5	..5	.5	.3	.3	.3
.5	.5	.5	.3	.3	.3	.5	.5	.5	.3	.3	.3
.5	.5	.5	.3	.3	.3	.5	.5	.5	.3	.3	.3

Nominal Position NIR Band

Pixel Reflectance Values
Misaligned Bands Scenario 2

.3	.3	.3	.1	.1	.1	.3	.3	.3	.1	.1	.1
.3	.3	.3	.1	.1	.1	.3	.3	.3	.1	.1	.1
.3	.3	.3	.1	.1	.1	.3	.3	.3	.1	.1	.1
.1	.1	.1	.3	.3	.3	.1	.1	.1	.3	.3	.3
.1	.1	.1	.3	.3	.3	.1	.1	.1	.3	.3	.3
.1	.1	.1	.3	.3	.3	.1	.1	.1	.3	.3	.3
.3	.3	.3	.1	.1	.1	.3	.3	.3	.1	.1	.1
.3	.3	.3	.1	.1	.1	.3	.3	.3	.1	.1	.1
.3	.3	.3	.1	.1	.1	.3	.3	.3	.1	.1	.1
.1	.1	.1	.3	.3	.3	.1	.1	.1	.3	.3	.3
.1	.1	.1	.3	.3	.3	.1	.1	.1	.3	.3	.3
.1	.1	.1	.3	.3	.3	.1	.1	.1	.3	.3	.3

.3	.3	.4	.5	.5	.4	.3	.3	.4	.5	.5	.4
.3	.3	.4	.5	.5	.4	.3	.3	.4	.5	.5	.4
.3	.3	.4	.5	.5	.4	.3	.3	.4	.5	.5	.4
.5	.5	.4	.3	.3	.4	.5	..5	.4	.3	.3	.4
.5	.5	.4	.3	.3	.4	.5	.5	.4	.3	.3	.4
.5	.5	.4	.3	.3	.4	.5	.5	.4	.3	.3	.4
.3	.3	.4	.5	.5	.4	.3	.3	.4	.5	.5	.4
.3	.3	.4	.5	.5	.4	.3	.3	.4	.5	.5	.4
.3	.3	.4	.5	.5	.4	.3	.3	.4	.5	.5	.4
.5	.5	.4	.3	.3	.4	.5	..5	.4	.3	.3	.4
.5	.5	.4	.3	.3	.4	.5	.5	.4	.3	.3	.4
.5	.5	.4	.3	.3	.4	.5	.5	.4	.3	.3	.4

Nominal Position VIS Band

"Half-pixel" Shift NIR Band

Nominal Position NIR Band

.3	.3	.3	.5	.5	.5	.3	.3	.3	.5	.5	.5
.3	.3	.3	.5	.5	.5	.3	.3	.3	.5	.5	.5
.3	.3	.3	.5	.5	.5	.3	.3	.3	.5	.5	.5
.5	..5	.5	.3	.3	.3	.5	..5	.5	.3	.3	.3
.5	.5	.5	.3	.3	.3	.5	.5	.5	.3	.3	.3
.5	.5	.5	.3	.3	.3	.5	.5	.5	.3	.3	.3
.3	.3	.3	.5	.5	.5	.3	.3	.3	.5	.5	.5
.3	.3	.3	.5	.5	.5	.3	.3	.3	.5	.5	.5
.3	.3	.3	.5	.5	.5	.3	.3	.3	.5	.5	.5
.5	..5	.5	.3	.3	.3	.5	.5	.5	.3	.3	.3
.5	.5	.5	.3	.3	.3	.5	.5	.5	.3	.3	.3
.5	.5	.5	.3	.3	.3	.5	.5	.5	.3	.3	.3

Nominal Position VIS Band

.3	.3	.3	.1	.1	.1	.3	.3	.3	.1	.1	.1
.3	.3	.3	.1	.1	.1	.3	.3	.3	.1	.1	.1
.3	.3	.3	.1	.1	.1	.3	.3	.3	.1	.1	.1
.1	.1	.1	.3	.3	.3	.1	.1	.1	.3	.3	.3
.1	.1	.1	.3	.3	.3	.1	.1	.1	.3	.3	.3
.1	.1	.1	.3	.3	.3	.1	.1	.1	.3	.3	.3
.3	.3	.3	.1	.1	.1	.3	.3	.3	.1	.1	.1
.3	.3	.3	.1	.1	.1	.3	.3	.3	.1	.1	.1
.3	.3	.3	.1	.1	.1	.3	.3	.3	.1	.1	.1
.1	.1	.1	.3	.3	.3	.1	.1	.1	.3	.3	.3
.1	.1	.1	.3	.3	.3	.1	.1	.1	.3	.3	.3
.1	.1	.1	.3	.3	.3	.1	.1	.1	.3	.3	.3

=

Study Basis

bands perfectly aligned

1	1	1	5	5	5	1	1	1	5	5	5
1	1	1	5	5	5	1	1	1	5	5	5
1	1	1	5	5	5	1	1	1	5	5	5
5	5	5	1	1	1	5	5	5	1	1	1
5	5	5	1	1	1	5	5	5	1	1	1
5	5	5	1	1	1	5	5	5	1	1	1
1	1	1	5	5	5	1	1	1	5	5	5
1	1	1	5	5	5	1	1	1	5	5	5
1	1	1	5	5	5	1	1	1	5	5	5
5	5	5	1	1	1	5	5	5	1	1	1
5	5	5	1	1	1	5	5	5	1	1	1
5	5	5	1	1	1	5	5	5	1	1	1

$$\frac{\text{NIR-Reflectance}}{\text{VIS-Reflectance}} = \text{VI}$$

Study Scenario 1

Nominal Position NIR Band

.3	.3	.3	.5	.5	.5	.3	.3	.3	.5	.5	.5
.3	.3	.3	.5	.5	.5	.3	.3	.3	.5	.5	.5
.3	.3	.3	.5	.5	.5	.3	.3	.3	.5	.5	.5
.5	..5	.5	.3	.3	.3	.5	..5	.5	.3	.3	.3
.5	.5	.5	.3	.3	.3	.5	.5	.5	.3	.3	.3
.5	.5	.5	.3	.3	.3	.5	.5	.5	.3	.3	.3
.3	.3	.3	.5	.5	.5	.3	.3	.3	.5	.5	.5
.3	.3	.3	.5	.5	.5	.3	.3	.3	.5	.5	.5
.3	.3	.3	.5	.5	.5	.3	.3	.3	.5	.5	.5
.5	..5	.5	.3	.3	.3	.5	.5	.5	.3	.3	.3
.5	.5	.5	.3	.3	.3	.5	.5	.5	.3	.3	.3
.5	.5	.5	.3	.3	.3	.5	.5	.5	.3	.3	.3

“Half-pixel” Shift VIS Band

.3	.3	.2	.1	.1	.2	.3	.3	.2	.1	.1	.2
.3	.3	.2	.1	.1	.2	.3	.3	.2	.1	.1	.2
.3	.3	.2	.1	.1	.2	.3	.3	.2	.1	.1	.2
.1	.1	.2	.3	.3	.2	.1	.1	.2	.3	.3	.2
.1	.1	.2	.3	.3	.2	.1	.1	.2	.3	.3	.2
.1	.1	.2	.3	.3	.2	.1	.1	.2	.3	.3	.2
.3	.3	.2	.1	.1	.2	.1	.1	.2	.1	.1	.2
.3	.3	.2	.1	.1	.2	.1	.1	.2	.1	.1	.2
.3	.3	.2	.1	.1	.2	.1	.1	.2	.1	.1	.2
.1	.1	.2	.3	.3	.2	.1	.1	.2	.3	.3	.2
.1	.1	.2	.3	.3	.2	.1	.1	.2	.3	.3	.2
.1	.1	.2	.3	.3	.2	.1	.1	.2	.3	.3	.2

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1	1	1.5	5	5	2.5	1	1	1.5	5	5	2.5
1	1	1.5	5	5	2.5	1	1	1.5	5	5	2.5
1	1	1.5	5	5	2.5	1	1	1.5	5	5	2.5
5	5	2.5	1	1	1.5	5	5	2.5	1	1	1.5
5	5	2.5	1	1	1.5	5	5	2.5	1	1	1.5
5	5	2.5	1	1	1.5	5	5	2.5	1	1	1.5
1	1	1.5	5	5	2.5	1	1	1.5	5	5	2.5
1	1	1.5	5	5	2.5	1	1	1.5	5	5	2.5
1	1	1.5	5	5	2.5	1	1	1.5	5	5	2.5
5	5	2.5	1	1	1.5	5	5	2.5	1	1	1.5
5	5	2.5	1	1	1.5	5	5	2.5	1	1	1.5
5	5	2.5	1	1	1.5	5	5	2.5	1	1	1.5

$$\frac{\text{NIR-Reflectance}}{\text{VIS-Reflectance}} = \text{VI}$$

Study Scenario 1

misalignment "corrected"

Nominal Position NIR Band

.3	.3	.3	.5	.5	.5	.3	.3	.3	.5	.5	.5
.3	.3	.3	.5	.5	.5	.3	.3	.3	.5	.5	.5
.3	.3	.3	.5	.5	.5	.3	.3	.3	.5	.5	.5
.5	..5	.5	.3	.3	.3	.5	..5	.5	.3	.3	.3
.5	.5	.5	.3	.3	.3	.5	.5	.5	.3	.3	.3
.5	.5	.5	.3	.3	.3	.5	.5	.5	.3	.3	.3
.3	.3	.3	.5	.5	.5	.3	.3	.3	.5	.5	.5
.3	.3	.3	.5	.5	.5	.3	.3	.3	.5	.5	.5
.3	.3	.3	.5	.5	.5	.3	.3	.3	.5	.5	.5
.5	..5	.5	.3	.3	.3	.5	.5	.5	.3	.3	.3
.5	.5	.5	.3	.3	.3	.5	.5	.5	.3	.3	.3
.5	.5	.5	.3	.3	.3	.5	.5	.5	.3	.3	.3

"Half-pixel" Resampled VIS Band

.25	.3	.25	.15	.1	.15	.25	.3	.25	.15	.1	.15
.25	.3	.25	.15	.1	.15	.25	.3	.25	.15	.1	.15
.25	.3	.25	.15	.1	.15	.25	.3	.25	.15	.1	.15
.15	.1	.15	.25	.3	.25	.15	.1	.15	.25	.3	.25
.15	.1	.15	.25	.3	.25	.15	.1	.15	.25	.3	.25
.15	.1	.15	.25	.3	.25	.15	.1	.15	.25	.3	.25
.25	.3	.25	.15	.1	.15	.25	.3	.25	.15	.1	.15
.25	.3	.25	.15	.1	.15	.25	.3	.25	.15	.1	.15
.25	.3	.25	.15	.1	.15	.25	.3	.25	.15	.1	.15
.15	.1	.15	.25	.3	.25	.15	.1	.15	.25	.3	.25
.15	.1	.15	.25	.3	.25	.15	.1	.15	.25	.3	.25
.15	.1	.15	.25	.3	.25	.15	.1	.15	.25	.3	.25

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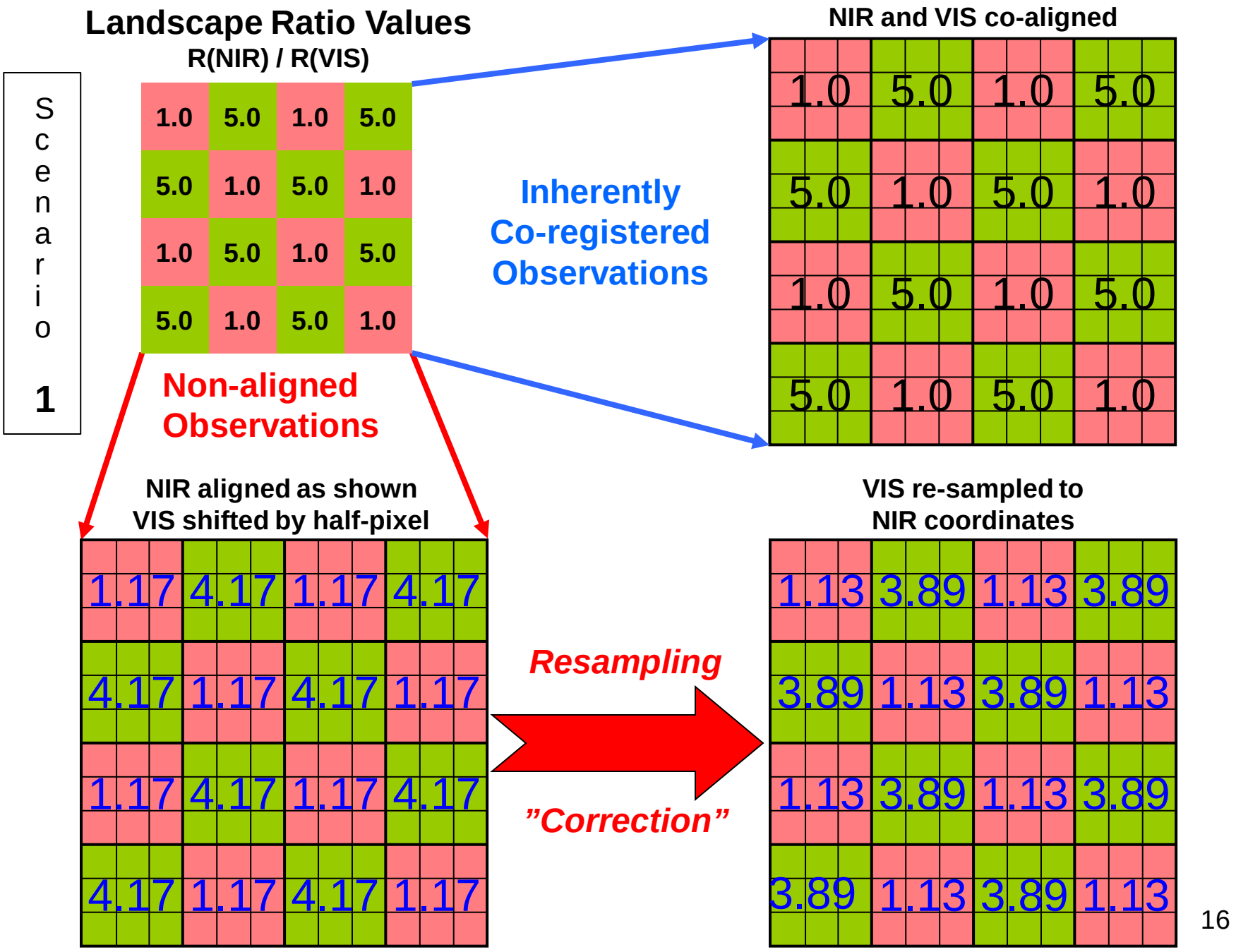
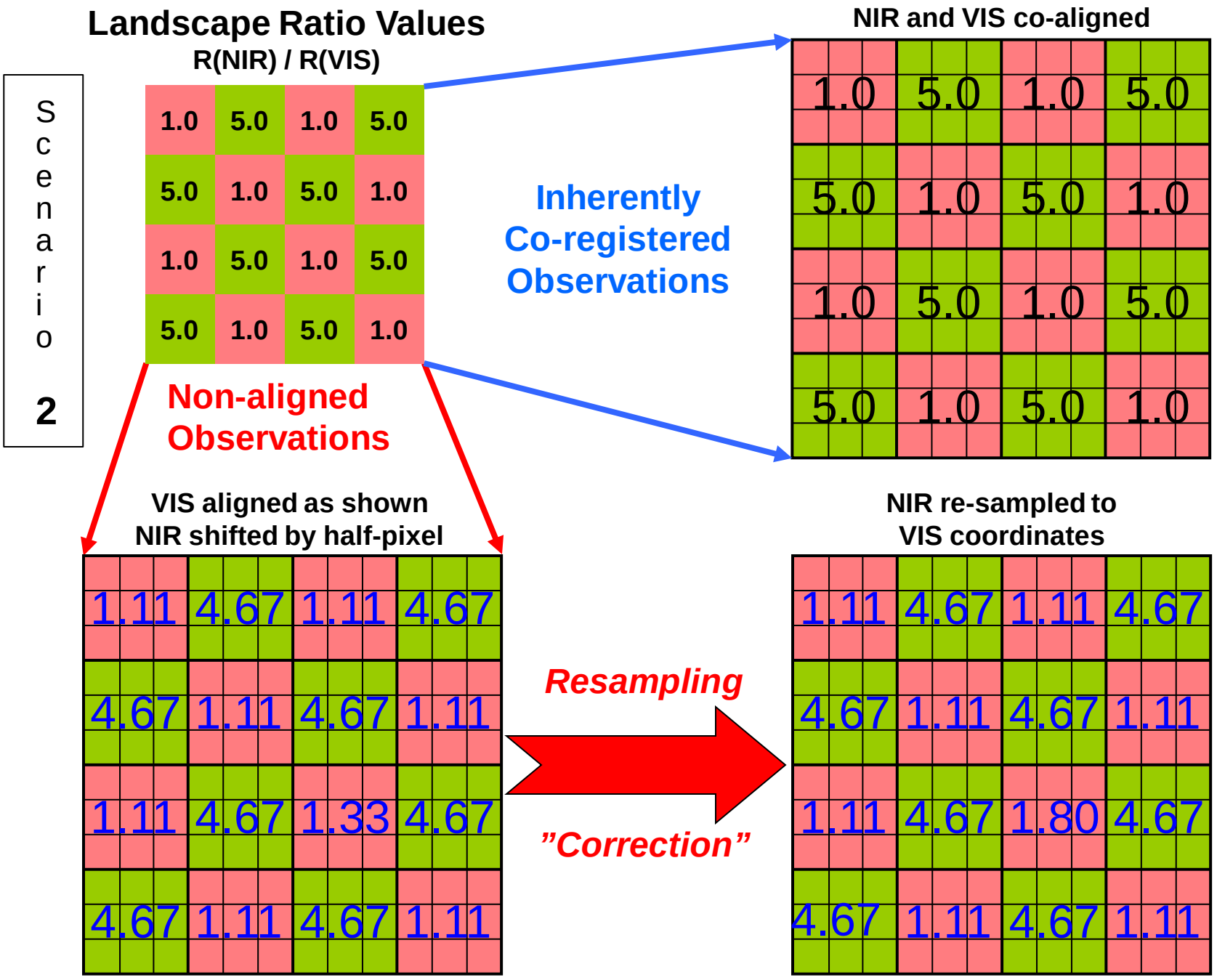
1.2	1	1.2	3.3	5	3.3	1.2	1	1.2	3.3	5	3.3
1.2	1	1.2	3.3	5	3.3	1.2	1	1.2	3.3	5	3.3
1.2	1	1.2	3.3	5	3.3	1.2	1	1.2	3.3	5	3.3
3.3	5	3.3	1.2	1	1.2	3.3	5	3.3	1.2	1	1.2
3.3	5	3.3	1.2	1	1.2	3.3	5	3.3	1.2	1	1.2
3.3	5	3.3	1.2	1	1.2	3.3	5	3.3	1.2	1	1.2
1.2	1	1.2	3.3	5	3.3	1.2	1	1.2	3.3	5	3.3
1.2	1	1.2	3.3	5	3.3	1.2	1	1.2	3.3	5	3.3
1.2	1	1.2	3.3	5	3.3	1.2	1	1.2	3.3	5	3.3
3.3	5	3.3	1.2	1	1.2	3.3	5	3.3	1.2	1	1.2
3.3	5	3.3	1.2	1	1.2	3.3	5	3.3	1.2	1	1.2
3.3	5	3.3	1.2	1	1.2	3.3	5	3.3	1.2	1	1.2

$$\frac{\text{NIR-Reflectance}}{\text{VIS-Reflectance}} = \text{VI}$$


Landscape Ratio Values
R(NIR) / R(VIS)
Scenario 1
1.0 5.0 1.0 5.0
5.0 1.0 5.0 1.0
1.0 5.0 1.0 5.0
5.0 1.0 5.0 1.0
Inherently Co-registered Observations
NIR and VIS co-aligned
1.0 5.0 1.0 5.0
5.0 1.0 5.0 1.0
1.0 5.0 1.0 5.0
5.0 1.0 5.0 1.0
Non-aligned Observations
NIR aligned as shown
VIS shifted by half-pixel
1.17 4.17 1.17 4.17
4.17 1.17 4.17 1.17
1.17 4.17 1.17 4.17
4.17 1.17 4.17 1.17
Resampling
"Correction"
VIS re-sampled to NIR coordinates
1.13 3.89 1.13 3.89
3.89 1.13 3.89 1.13
1.13 3.89 1.13 3.89
3.89 1.13 3.89 1.13

Results of half pixel misalignment and correction through linear re-sampling

Scenario 1	Category 1 Ratio Value	Category 1 Discrepancy	Category 2 Ratio Value	Category 2 Discrepancy
VIS and NIR co-aligned	1.00	0%	5.00	0%
VIS and NIR misaligned	1.17	+17%	4.17	-17%
VIS realigned by resampling	1.13	+13%	3.89	-22%


Landscape Ratio Values
R(NIR) / R(VIS)
Scenario 2
1.0 5.0 1.0 5.0
5.0 1.0 5.0 1.0
1.0 5.0 1.0 5.0
5.0 1.0 5.0 1.0
Inherently Co-registered Observations
NIR and VIS co-aligned
1.0 5.0 1.0 5.0
5.0 1.0 5.0 1.0
1.0 5.0 1.0 5.0
5.0 1.0 5.0 1.0
Non-aligned Observations
VIS aligned as shown
NIR shifted by half-pixel
1.11 4.67 1.11 4.67
4.67 1.11 4.67 1.11
1.11 4.67 1.33 4.67
4.67 1.11 4.67 1.11
Resampling
"Correction"
NIR re-sampled to VIS coordinates
1.11 4.67 1.11 4.67
4.67 1.11 4.67 1.11
1.11 4.67 1.80 4.67
4.67 1.11 4.67 1.11

Results of half pixel misalignment and correction through linear re-sampling

Scenario 2	Category 1 Ratio Value	Category 1 Discrepancy	Category 2 Ratio Value	Category 2 Discrepancy
VIS and NIR co-aligned	1.00	0%	5.00	0%
VIS and NIR misaligned	1.11	+11%	4.67	-7%
NIR realigned by resampling	1.11	+11%	4.67	-7%

Can we expect perfect observing systems to agree with each other?

NO! For multi-spectral *(i.e. hypo-spectral)* observing systems.

YES! For full spectral *(i.e. hyper-spectral)* observing systems.

Thank you Joe Boardman!

Why don't perfect multi-spectral systems agree with each other?

Most landscapes of interest, observed at *"moderate"* resolution, are comprised of a large number of *"mixed"* pixels.

There usually is insufficient information to find a *unique* *"unmixed" solution.*

Multi-Spectral systems are under determined!

Shifted Scenario

“Half-pixel” Shift NIR Band

.3	.3	.4	.5	.5	.4	.3	.3	.4	.5	.5	.4
.3	.3	.4	.5	.5	.4	.3	.3	.4	.5	.5	.4
.3	.3	.4	.5	.5	.4	.3	.3	.4	.5	.5	.4
.5	.5	.4	.3	.3	.4	.5	..5	.4	.3	.3	.4
.5	.5	.4	.3	.3	.4	.5	.5	.4	.3	.3	.4
.5	.5	.4	.3	.3	.4	.5	.5	.4	.3	.3	.4
.3	.3	.4	.5	.5	.4	.3	.3	.4	.5	.5	.4
.3	.3	.4	.5	.5	.4	.3	.3	.4	.5	.5	.4
.3	.3	.4	.5	.5	.4	.3	.3	.4	.5	.5	.4
.5	.5	.4	.3	.3	.4	.5	..5	.4	.3	.3	.4
.5	.5	.4	.3	.3	.4	.5	.5	.4	.3	.3	.4
.5	.5	.4	.3	.3	.4	.5	.5	.4	.3	.3	.4

“Half-pixel” Shift VIS Band

.3	.3	.2	.1	.1	.2	.3	.3	.2	.1	.1	.2
.3	.3	.2	.1	.1	.2	.3	.3	.2	.1	.1	.2
.3	.3	.2	.1	.1	.2	.3	.3	.2	.1	.1	.2
.1	.1	.2	.3	.3	.2	.1	.1	.2	.3	.3	.2
.1	.1	.2	.3	.3	.2	.1	.1	.2	.3	.3	.2
.1	.1	.2	.3	.3	.2	.1	.1	.2	.3	.3	.2
.3	.3	.2	.1	.1	.2	.1	.1	.2	.1	.1	.2
.3	.3	.2	.1	.1	.2	.1	.1	.2	.1	.1	.2
.3	.3	.2	.1	.1	.2	.1	.1	.2	.1	.1	.2
.1	.1	.2	.3	.3	.2	.1	.1	.2	.3	.3	.2
.1	.1	.2	.3	.3	.2	.1	.1	.2	.3	.3	.2
.1	.1	.2	.3	.3	.2	.1	.1	.2	.3	.3	.2

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1	1	2	5	5	2	1	1	2	5	5	2
1	1	2	5	5	2	1	1	2	5	5	2
1	1	2	5	5	2	1	1	2	5	5	2
5	5	2	1	1	2	5	5	2	1	1	2
5	5	2	1	1	2	5	5	2	1	1	2
5	5	2	1	1	2	5	5	2	1	1	2
1	1	2	5	5	2	1	1	2	5	5	2
1	1	2	5	5	2	1	1	2	5	5	2
1	1	2	5	5	2	1	1	2	5	5	2
5	5	2	1	1	2	5	5	2	1	1	2
5	5	2	1	1	2	5	5	2	1	1	2
5	5	2	1	1	2	5	5	2	1	1	2

$$\frac{\text{NIR-Reflectance}}{\text{VIS-Reflectance}} = \text{VI}$$

“Half-pixel” Resampled NIR Band

.35	.3	.35	.45	.5	.45	.35	.3	.35	.45	.5	.45
.35	.3	.35	.45	.5	.45	.35	.3	.35	.45	.5	.45
.35	.3	.35	.45	.5	.45	.35	.3	.35	.45	.5	.45
.45	.5	.45	.35	.3	.35	.45	.5	.45	.35	.3	.35
.45	.5	.45	.35	.3	.35	.45	.5	.45	.35	.3	.35
.45	.5	.45	.35	.3	.35	.45	.5	.45	.35	.3	.35
.35	.3	.35	.45	.5	.45	.35	.3	.35	.45	.5	.45
.35	.3	.35	.45	.5	.45	.35	.3	.35	.45	.5	.45
.35	.3	.35	.45	.5	.45	.35	.3	.35	.45	.5	.45
.45	.5	.45	.35	.3	.35	.45	.5	.45	.35	.3	.35
.45	.5	.45	.35	.3	.35	.45	.5	.45	.35	.3	.35
.45	.5	.45	.35	.3	.35	.45	.5	.45	.35	.3	.35

“Half-pixel” Resampled VIS Band

.25	.3	.25	.15	.1	.15	.25	.3	.25	.15	.1	.15
.25	.3	.25	.15	.1	.15	.25	.3	.25	.15	.1	.15
.25	.3	.25	.15	.1	.15	.25	.3	.25	.15	.1	.15
.15	.1	.15	.25	.3	.25	.15	.1	.15	.25	.3	.25
.15	.1	.15	.3	.3	.25	.15	.1	.15	.25	.3	.25
.15	.1	.15	.3	.3	.25	.15	.1	.15	.25	.3	.25
.25	.3	.25	.15	.1	.15	.25	.3	.25	.15	.1	.15
.25	.3	.25	.15	.1	.15	.25	.3	.25	.15	.1	.15
.25	.3	.25	.15	.1	.15	.25	.3	.25	.15	.1	.15
.15	.1	.15	.25	.3	.25	.15	.1	.15	.25	.3	.25
.15	.1	.15	.25	.3	.25	.15	.1	.15	.25	.3	.25
.15	.1	.15	.25	.3	.25	.15	.1	.15	.25	.3	.25

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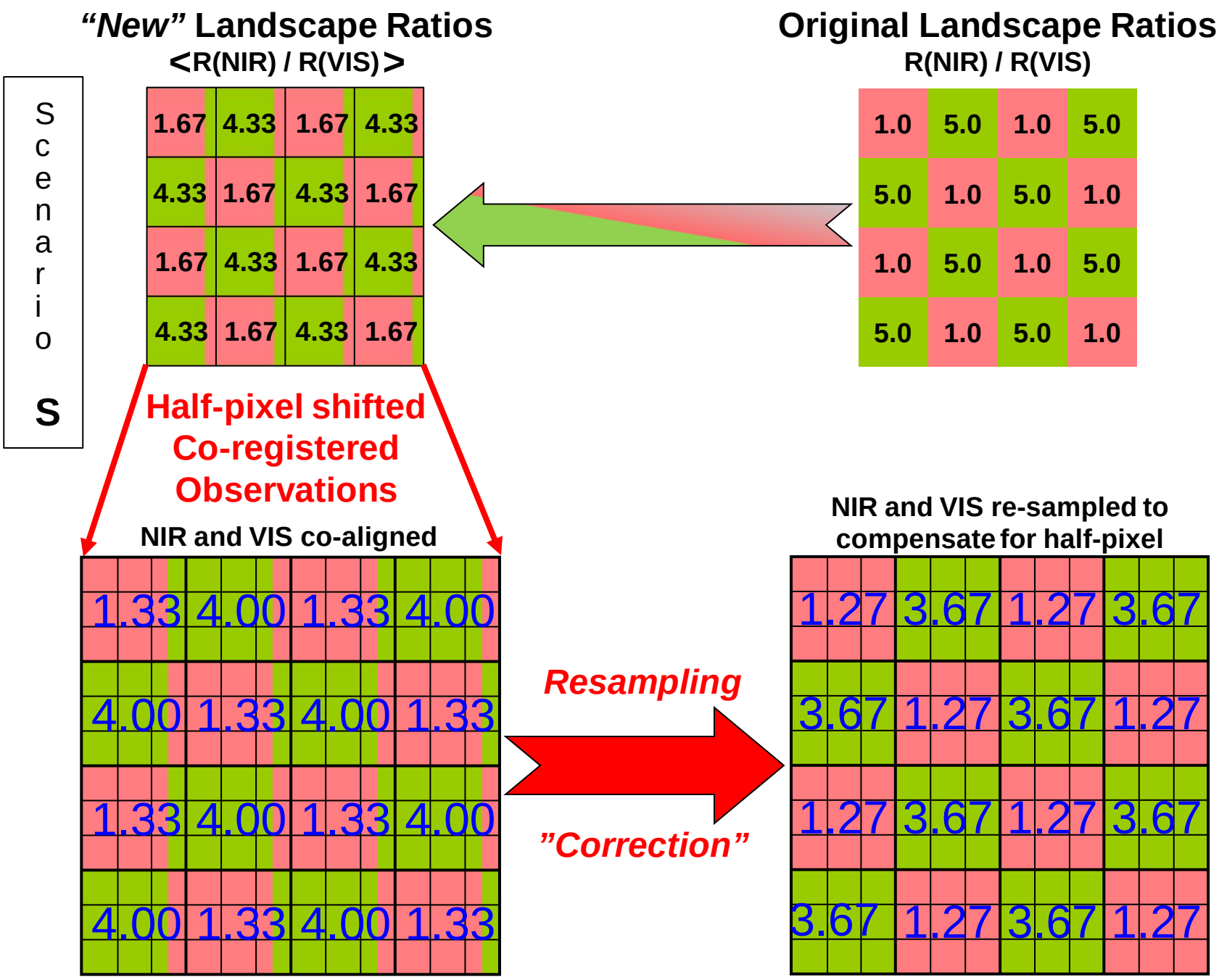
Shifted Scenario

misalignment “corrected”

1.4	1	1.4	3	5	3	1.4	1	1.4	3	5	3
1.4	1	1.4	3	5	3	1.4	1	1.4	3	5	3
1.4	1	1.4	3	5	3	1.4	1	1.4	3	5	3
3	5	3	1.4	1	1.4	3	5	3	1.4	1	1.4
3	5	3	1.4	1	1.4	3	5	3	1.4	1	1.4
3	5	3	1.4	1	1.4	3	5	3	1.4	1	1.4
1.4	1	1.4	3	5	3	1.4	1	1.4	3	5	3
1.4	1	1.4	3	5	3	1.4	1	1.4	3	5	3
1.4	1	1.4	3	5	3	1.4	1	1.4	3	5	3
3	5	3	1.4	1	1.4	3	5	3	1.4	1	1.4
3	5	3	1.4	1	1.4	3	5	3	1.4	1	1.4
3	5	3	1.4	1	1.4	3	5	3	1.4	1	1.4

$$\frac{\text{NIR-Reflectance}}{\text{VIS-Reflectance}} = \text{VI}$$

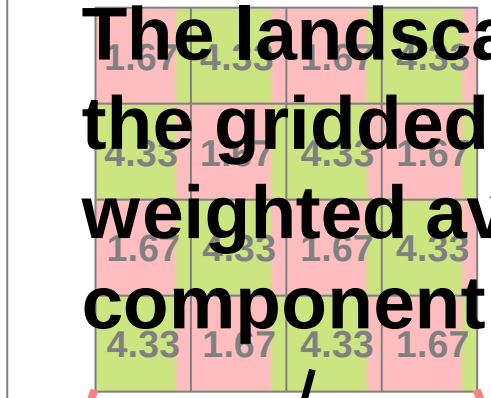

"New" Landscape Ratios
<R(NIR) / R(VIS)>
Original Landscape Ratios
R(NIR) / R(VIS)
Scenario S
1.67 4.33 1.67 4.33
4.33 1.67 4.33 1.67
1.67 4.33 1.67 4.33
4.33 1.67 4.33 1.67
1.0 5.0 1.0 5.0
5.0 1.0 5.0 1.0
1.0 5.0 1.0 5.0
5.0 1.0 5.0 1.0
Half-pixel shifted
Co-registered
Observations
NIR and VIS co-aligned
NIR and VIS re-sampled to
compensate for half-pixel
1.33 4.00 1.33 4.00
4.00 1.33 4.00 1.33
1.33 4.00 1.33 4.00
4.00 1.33 4.00 1.33
Resampling
"Correction"
1.27 3.67 1.27 3.67
3.67 1.27 3.67 1.27
1.27 3.67 1.27 3.67
3.67 1.27 3.67 1.27

Scenario S

"*New*" Landscape Ratios
<R(NIR) / R(VIS)>

Original Landscape Ratios
R(NIR) / R(VIS)

The landscape ratios shown in each of the gridded regions represents the areal weighted average of actual landscape component ratios.

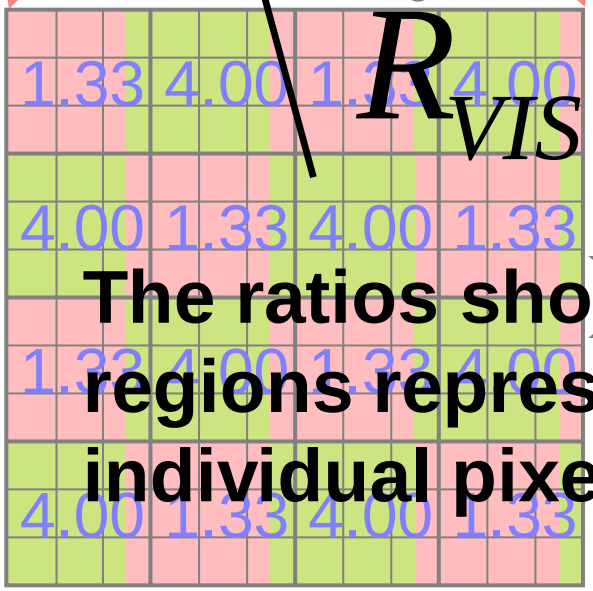


Half-pixel shifted Co-registered Observations

$$\left\langle \frac{R_{NIR}}{R_{VIS}} \right\rangle \neq \frac{\langle R_{NIR} \rangle}{\langle R_{VIS} \rangle}$$

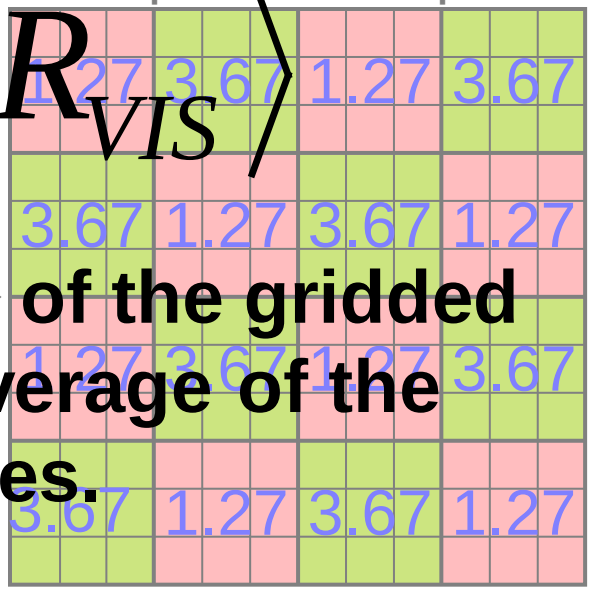
NIR and VIS co-aligned

NIR and VIS re-sampled to compensate for half-pixel

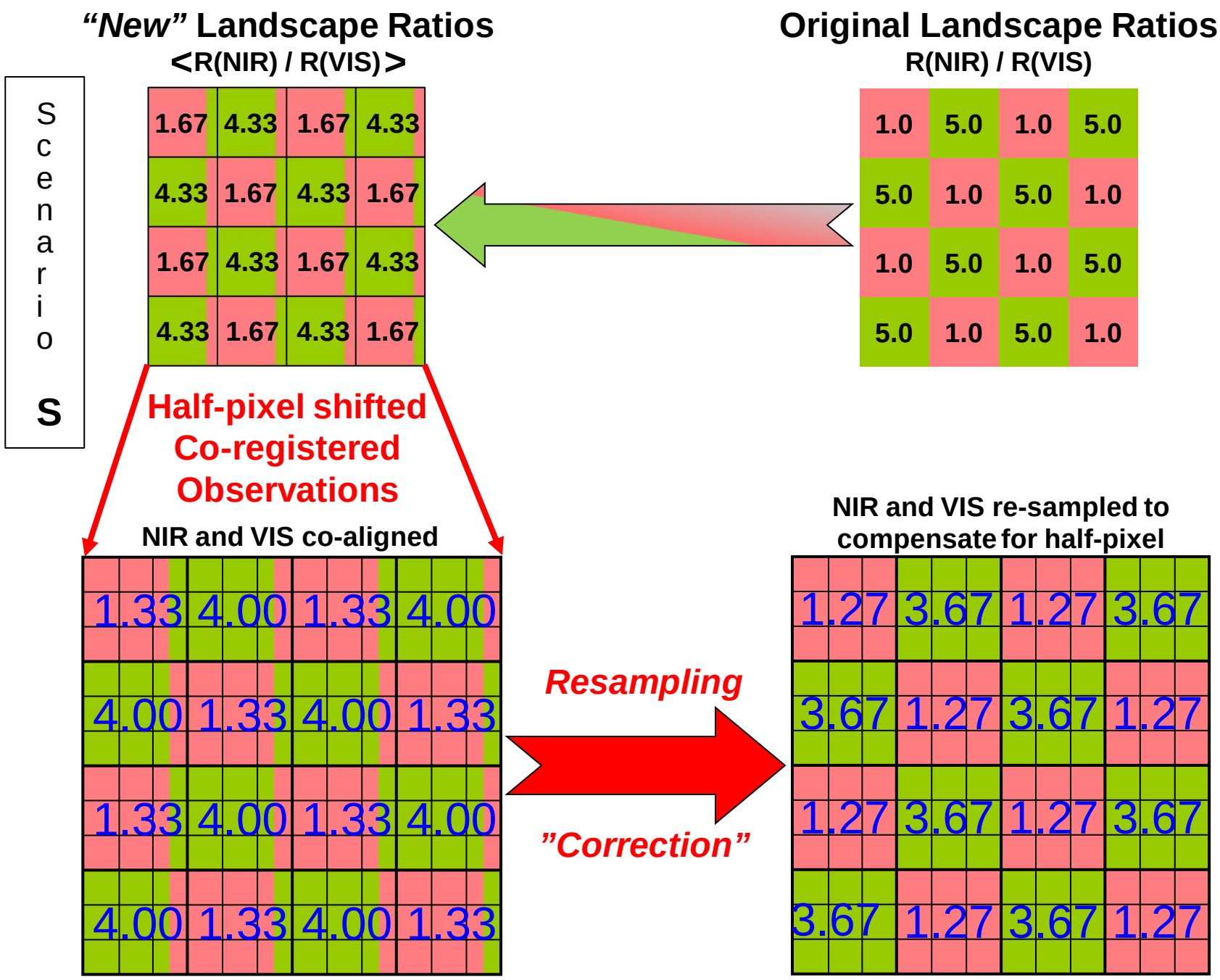


Resampling

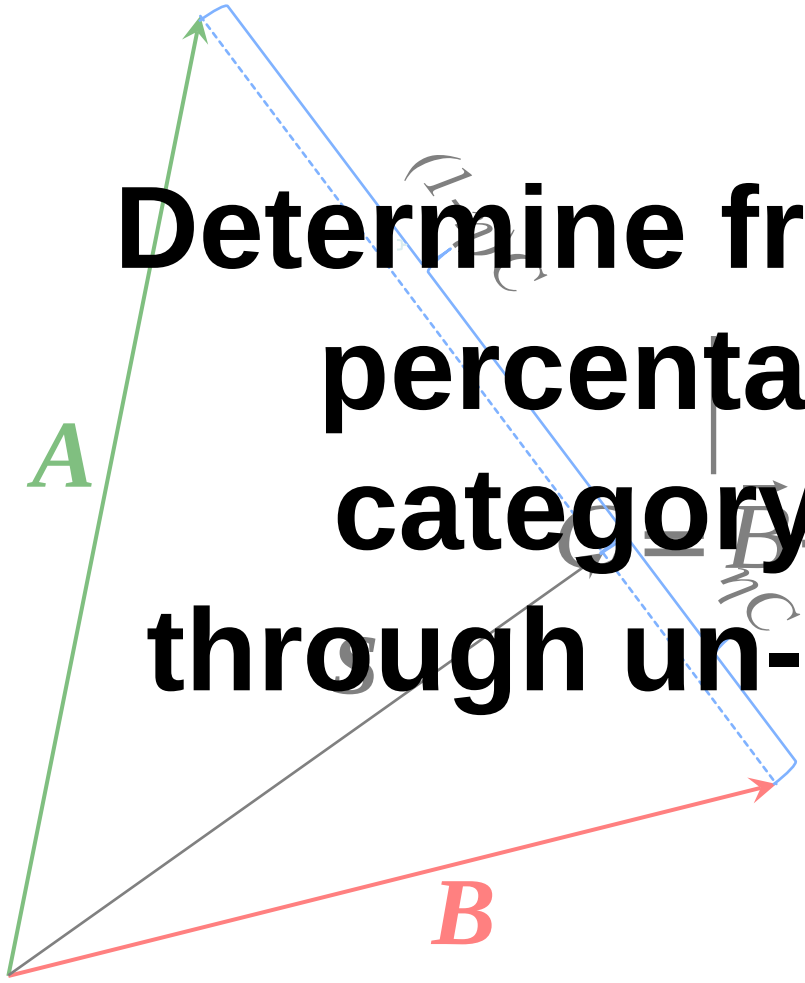
Correction



The ratios shown in each of the gridded regions represents the average of the individual pixel ratio values.


"New" Landscape Ratios
<R(NIR) / R(VIS)>
Original Landscape Ratios
R(NIR) / R(VIS)
Scenario S
1.67 4.33 1.67 4.33
4.33 1.67 4.33 1.67
1.67 4.33 1.67 4.33
4.33 1.67 4.33 1.67
1.0 5.0 1.0 5.0
5.0 1.0 5.0 1.0
1.0 5.0 1.0 5.0
5.0 1.0 5.0 1.0
Half-pixel shifted
Co-registered
Observations
NIR and VIS co-aligned
NIR and VIS re-sampled to
compensate for half-pixel
1.33 4.00 1.33 4.00
4.00 1.33 4.00 1.33
1.33 4.00 1.33 4.00
4.00 1.33 4.00 1.33
Resampling
"Correction"
1.27 3.67 1.27 3.67
3.67 1.27 3.67 1.27
1.27 3.67 1.27 3.67
3.67 1.27 3.67 1.27

Determine fractional cover percentage of each category (η and 1-η) through un-mixing model



$$\vec{S} = \eta\vec{A} + (1-\eta)\vec{B}$$

where: $0 \le \eta \le 1$

$$S_3 = \eta A_3 + (1-\eta)B_3$$

$$S_4 = \eta A_4 + (1-\eta)B_4$$

$$\eta = \frac{S_3 B_4 - S_4 B_3}{A_3 B_4 - A_4 B_3}$$

Ungar et al - 1970!

Shifted Scenario

“Half-pixel” Shift NIR Band

.3	.3	.4	.5	.5	.4	.3	.3	.4	.5	.5	.4
.3	.3	.4	.5	.5	.4	.3	.3	.4	.5	.5	.4
.3	.3	.4	.5	.5	.4	.3	.3	.4	.5	.5	.4
.5	.5	.4	.3	.3	.4	.5	..5	.4	.3	.3	.4
.5	.5	.4	.3	.3	.4	.5	.5	.4	.3	.3	.4
.5	.5	.4	.3	.3	.4	.5	.5	.4	.3	.3	.4
.3	.3	.4	.5	.5	.4	.3	.3	.4	.5	.5	.4
.3	.3	.4	.5	.5	.4	.3	.3	.4	.5	.5	.4
.3	.3	.4	.5	.5	.4	.3	.3	.4	.5	.5	.4
.5	.5	.4	.3	.3	.4	.5	..5	.4	.3	.3	.4
.5	.5	.4	.3	.3	.4	.5	.5	.4	.3	.3	.4
.5	.5	.4	.3	.3	.4	.5	.5	.4	.3	.3	.4

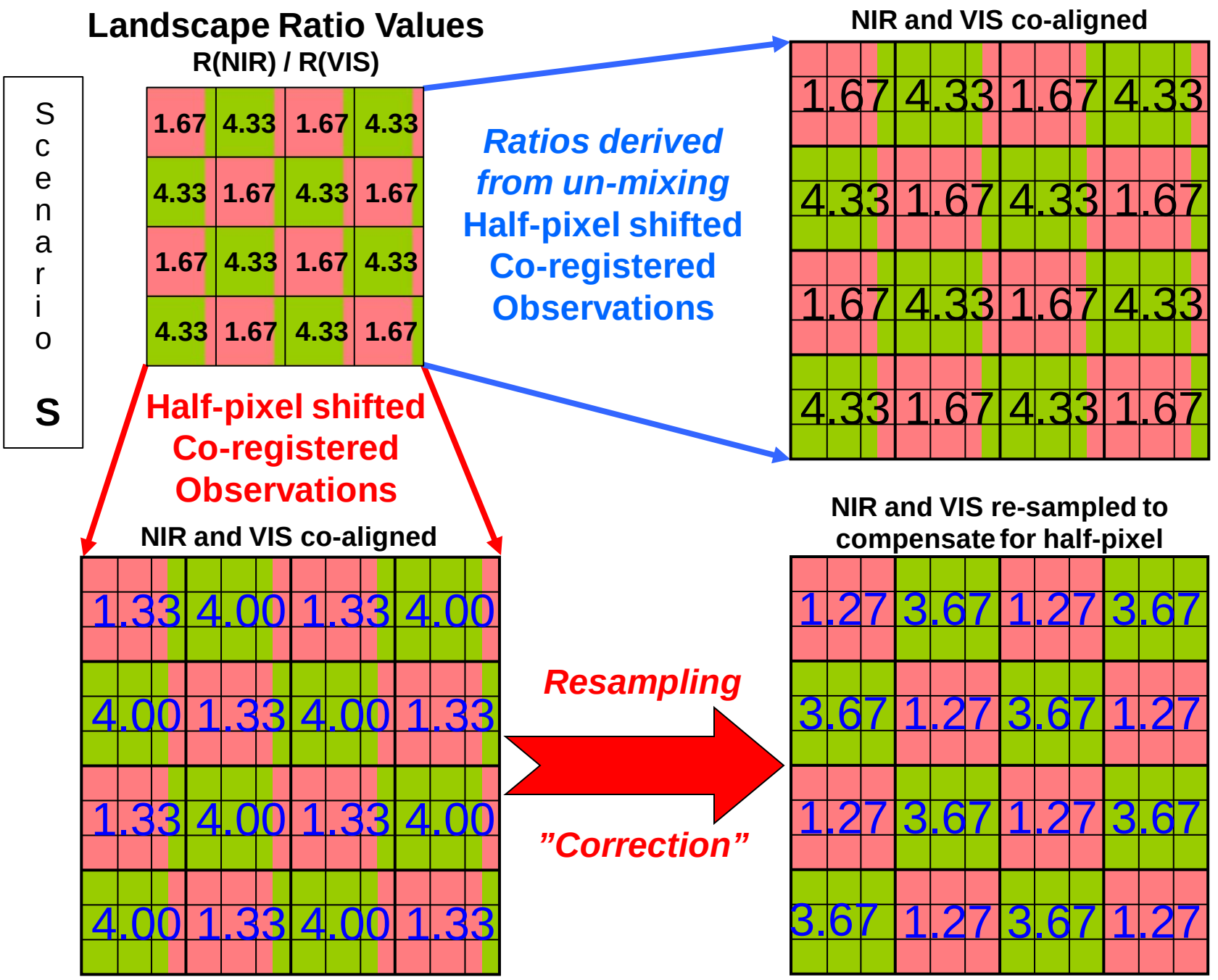
“Half-pixel” Shift VIS Band

.3	.3	.2	.1	.1	.2	.3	.3	.2	.1	.1	.2
.3	.3	.2	.1	.1	.2	.3	.3	.2	.1	.1	.2
.3	.3	.2	.1	.1	.2	.3	.3	.2	.1	.1	.2
.1	.1	.2	.3	.3	.2	.1	.1	.2	.3	.3	.2
.1	.1	.2	.3	.3	.2	.1	.1	.2	.3	.3	.2
.1	.1	.2	.3	.3	.2	.1	.1	.2	.3	.3	.2
.3	.3	.2	.1	.1	.2	.1	.1	.2	.1	.1	.2
.3	.3	.2	.1	.1	.2	.1	.1	.2	.1	.1	.2
.3	.3	.2	.1	.1	.2	.1	.1	.2	.1	.1	.2
.1	.1	.2	.3	.3	.2	.1	.1	.2	.3	.3	.2
.1	.1	.2	.3	.3	.2	.1	.1	.2	.3	.3	.2
.1	.1	.2	.3	.3	.2	.1	.1	.2	.3	.3	.2

=

1	1	3	5	5	3	1	1	3	5	5	3
1	1	3	5	5	3	1	1	3	5	5	3
1	1	3	5	5	3	1	1	3	5	5	3
5	5	3	1	1	3	5	5	3	1	1	3
5	5	3	1	1	3	5	5	3	1	1	3
5	5	3	1	1	3	5	5	3	1	1	3
1	1	3	5	5	3	1	1	3	5	5	3
1	1	3	5	5	3	1	1	3	5	5	3
1	1	3	5	5	3	1	1	3	5	5	3
5	5	3	1	1	3	5	5	3	1	1	3
5	5	3	1	1	3	5	5	3	1	1	3
5	5	3	1	1	3	5	5	3	1	1	3

Mixture Model $\left\langle \frac{R_{NIR}}{R_{VIS}} \right\rangle = VI$


Landscape Ratio Values
R(NIR) / R(VIS)
Scenario S
1.67 4.33 1.67 4.33
4.33 1.67 4.33 1.67
1.67 4.33 1.67 4.33
4.33 1.67 4.33 1.67
Ratios derived from un-mixing Half-pixel shifted Co-registered Observations
NIR and VIS co-aligned
1.67 4.33 1.67 4.33
4.33 1.67 4.33 1.67
1.67 4.33 1.67 4.33
4.33 1.67 4.33 1.67
Half-pixel shifted Co-registered Observations
NIR and VIS co-aligned
1.33 4.00 1.33 4.00
4.00 1.33 4.00 1.33
1.33 4.00 1.33 4.00
4.00 1.33 4.00 1.33
Resampling
"Correction"
NIR and VIS re-sampled to compensate for half-pixel
1.27 3.67 1.27 3.67
3.67 1.27 3.67 1.27
1.27 3.67 1.27 3.67
3.67 1.27 3.67 1.27

Results of half pixel misalignment and *"correction"* through linear re-sampling

Pixel Shift Scenario	Category 1 Ratio Value	Category 1 Discrepancy	Category 2 Ratio Value	Category 2 Discrepancy
VIS and NIR ½ pixel shift	*1.33*	*+33%*	*4.00*	*-20%*
VIS and NIR resampled	1.27	+27%	3.67	-26%
VIS and NIR unmixed	1.00	0%	5.00	0%

Pixel-shift/Band-misalignment Study Results

Averaged Scene Ratios	Ratio Value	Discrepancy	Ratio Value	Discrepancy
VIS and NIR co-aligned	3.00	0%		
VIS and NIR misaligned	*Scenario 1* 2.67	*Scenario 1* -11%	*Scenario 2* 2.89	*Scenario 2* -4%
realigned by re-sampling	*Scenario 1* 2.50	*Scenario 1* -17%	*Scenario 2* 2.89	*Scenario 2* -4%
VIS and NIR both shifted	2.67	-11%		
Shifted pixels re-sampled	2.47	-18%		
Shifted pixels unmixed	3.00	0%		

Inherent spectral/spatial integrity, required for HyspIRI, allows for substantially more accurate parameter determination than is possible with *currently planned* sequentially sampled pushbroom multispectral systems.

Unlike these multispectral systems, the rich spectral content offered by HyspIRI has the potential to mitigate the impact of temporal sampling offsets as well as to address mixed pixels.

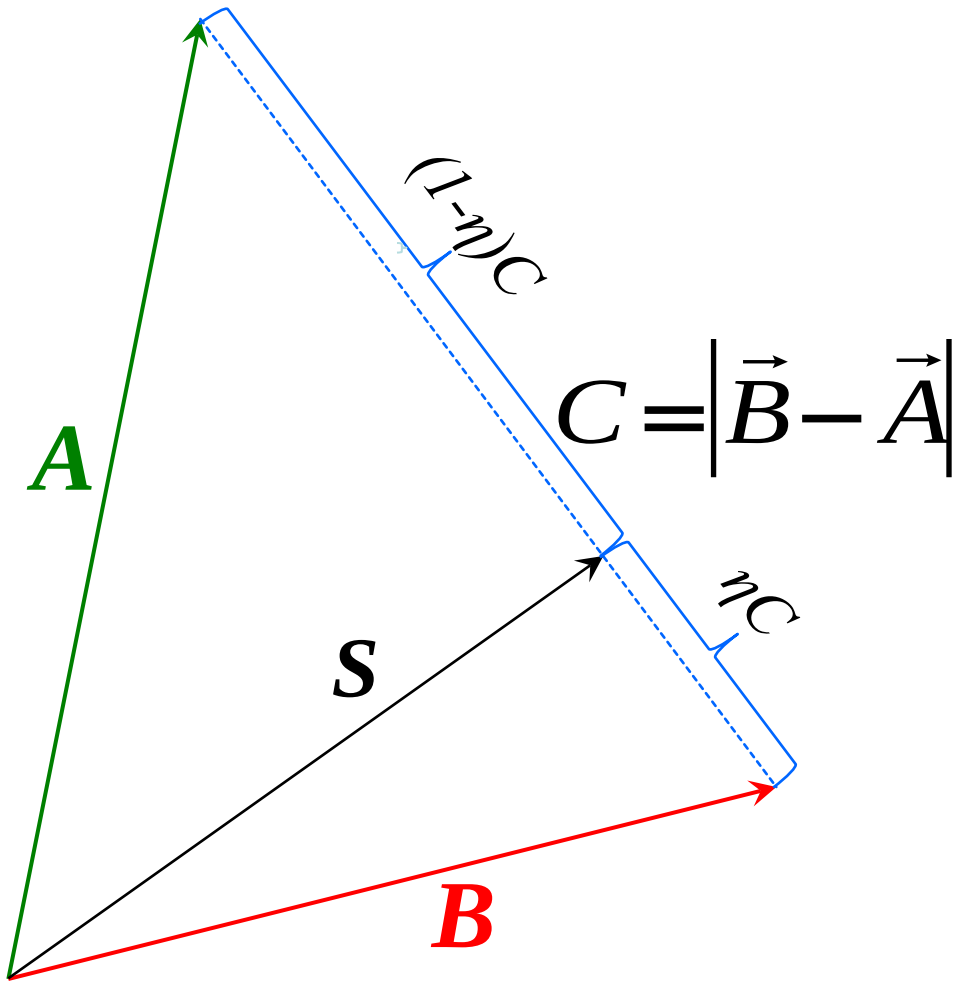
Band-to-Band Registration
The Bottom Line

$$\left\langle \frac{R_{NIR}}{R_{VIS}} \right\rangle \neq \frac{\langle R_{NIR} \rangle}{\langle R_{VIS} \rangle}$$

Band-to-Band Registration
However ……

$$\frac{64}{16} = \frac{64}{16} = \frac{4}{1} \equiv 4$$

Determine fractional cover percentage of each category (η and 1- η) through un-mixing model



$$\vec{S}=\eta\vec{A}+(1-\eta)\vec{B}$$

where: $0\le\eta\le1$

$$S_3=\eta A_3+(1-\eta)B_3$$
$$S_4=\eta A_4+(1-\eta)B_4$$

$$\eta=\frac{S_3B_4-S_4B_3}{A_3B_4-A_4B_3}$$