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Using Image Tour to Explore Multiangle, Multispectral Satellite Imagery

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Automated Decisions

The Problem

- How to understand structure of high-dimensional data while maintaining spatial (and temporal) context?
- Usual approach: make lots of maps (and maybe animate them).

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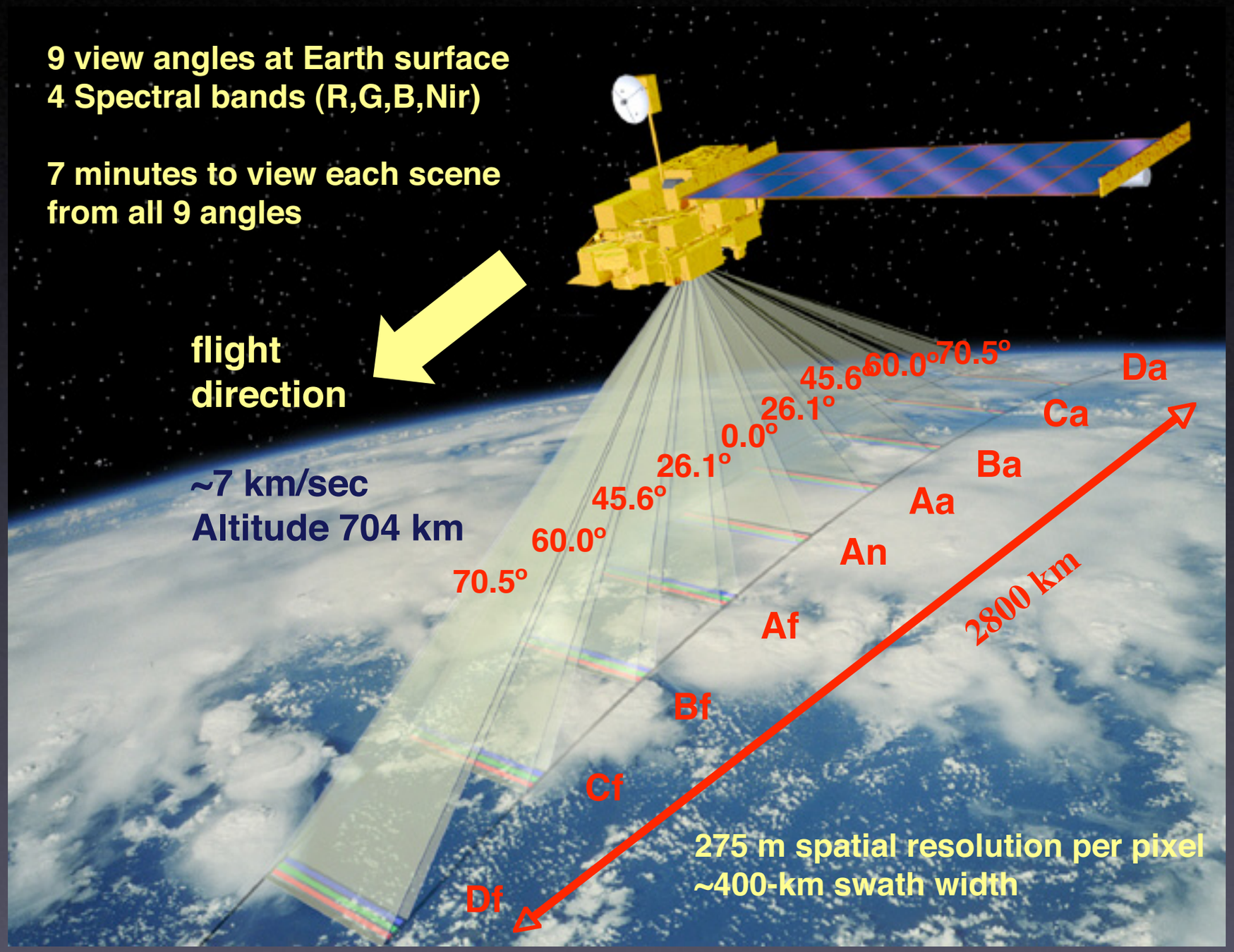
Multiangle Imaging SpectroRadiometer



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Multiangle Imaging SpectroRadiometer

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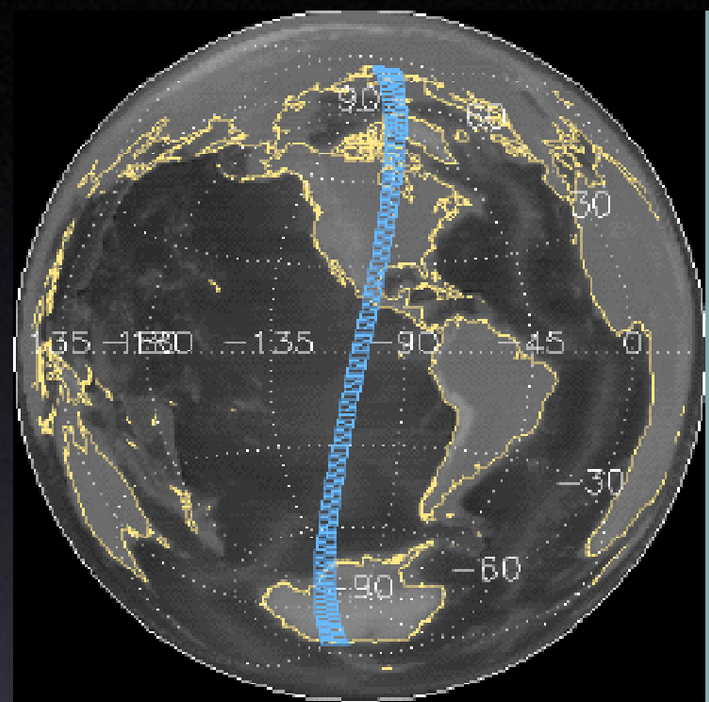
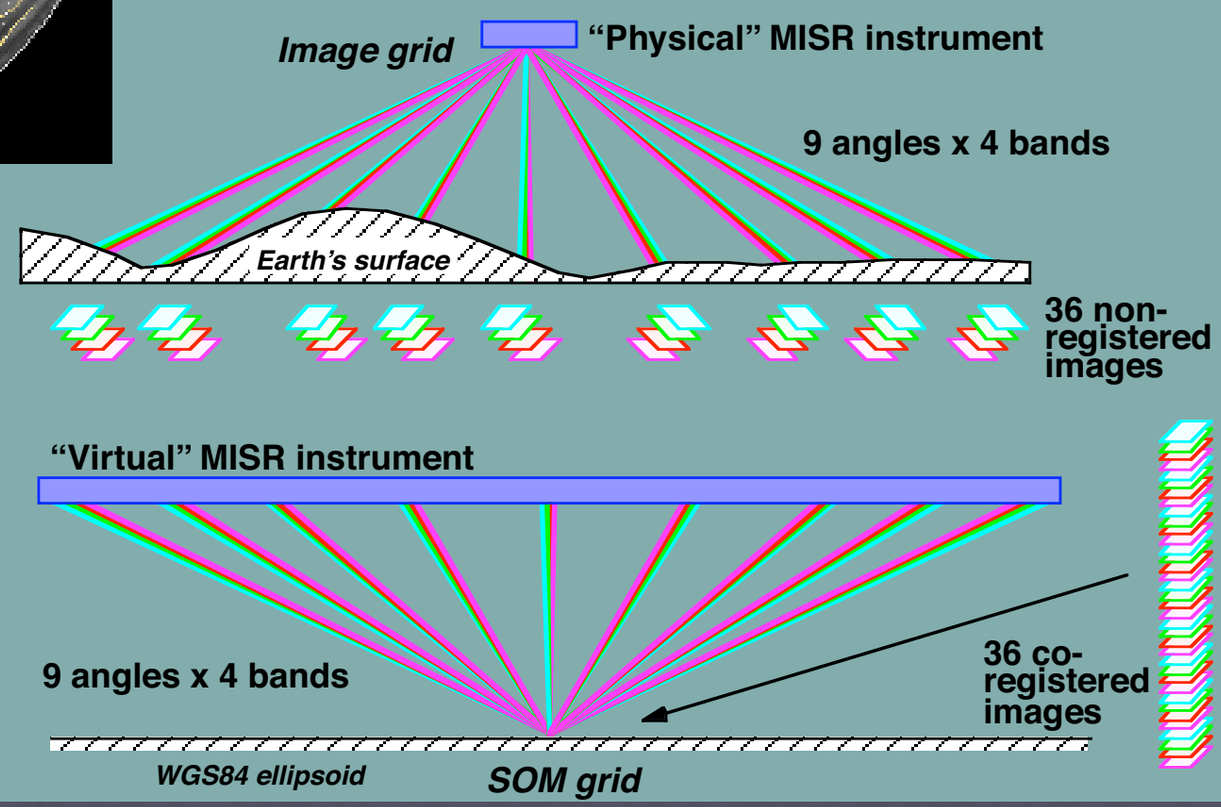
Multiangle Imaging SpectroRadiometer



Geolocation, resampling, and co-registration occurs during Level 1 processing

Space Oblique Mercator projection

233 unique paths in 16-day repeat-cycle of Terra orbit



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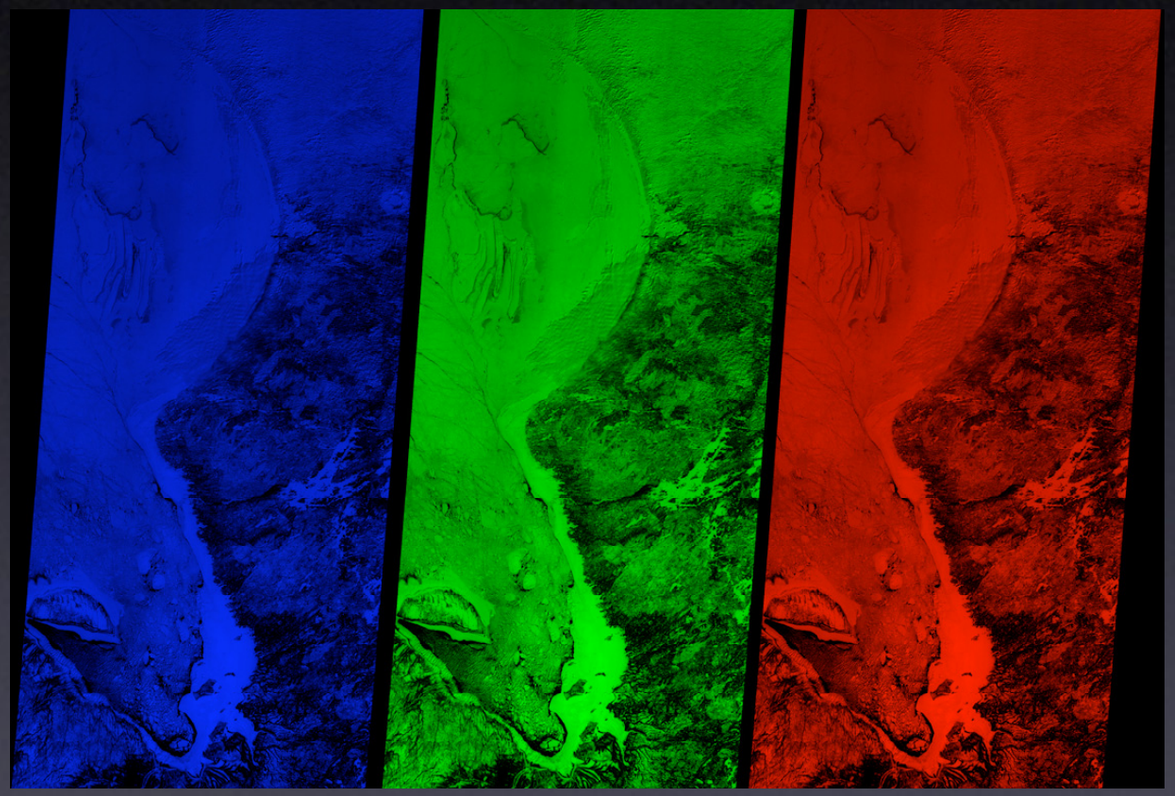
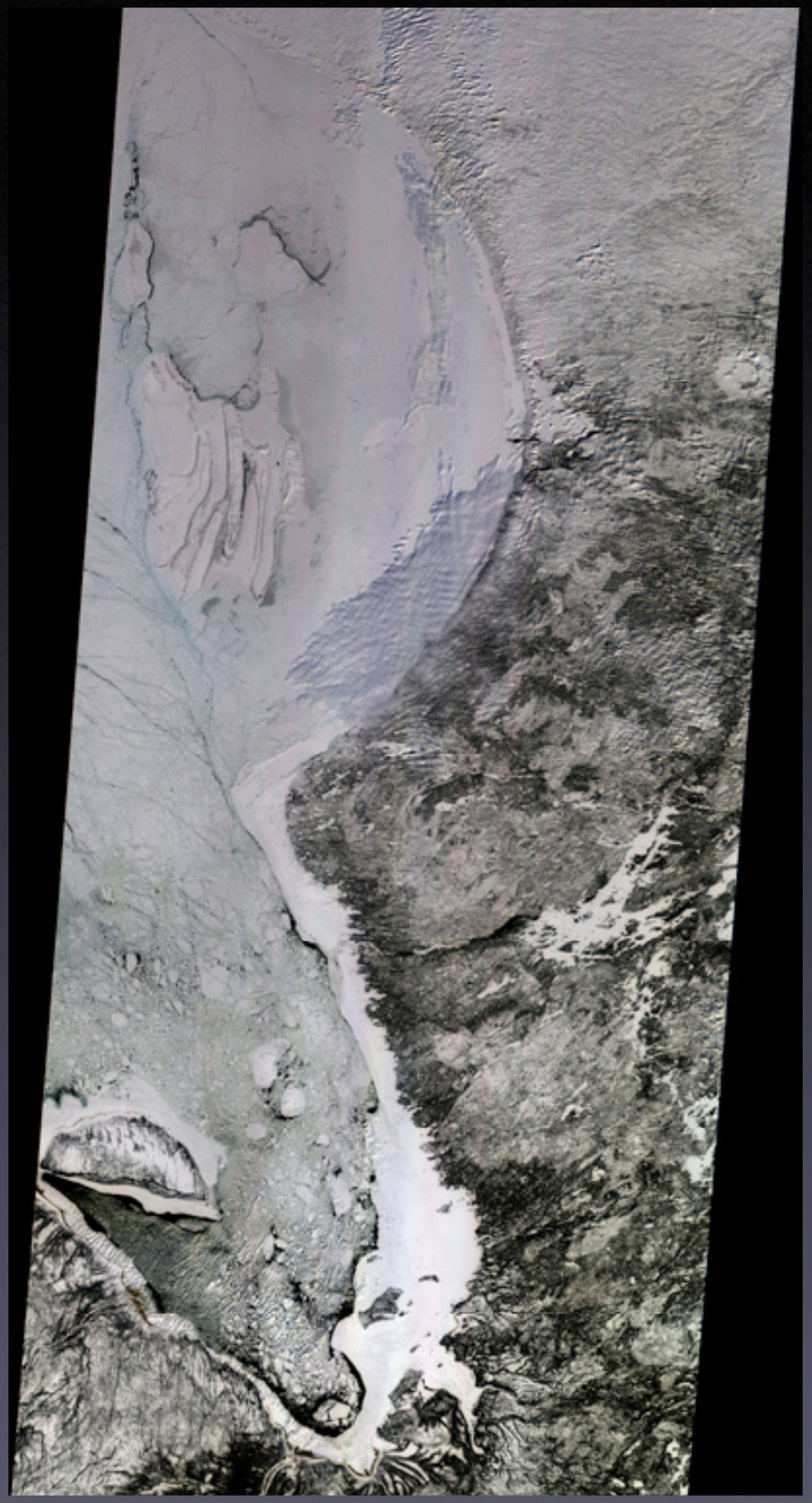
Multiangle Imaging SpectroRadiometer

nadir blue band | **nadir green band** | **nadir red band**



multi-spectral compositing

Hudson and James Bays 24 February 2000



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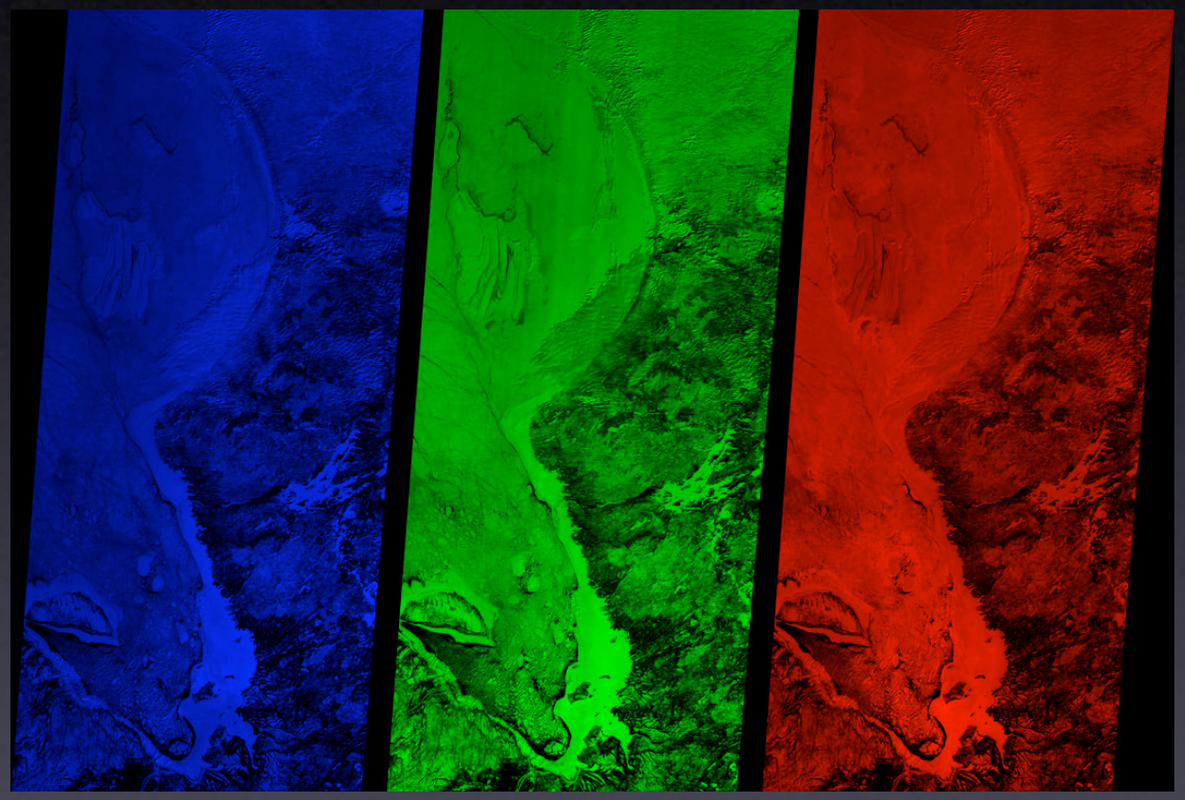
Multiangle Imaging SpectroRadiometer

70° forward red band | **nadir red band** | **70° backward red band**



multi-angular compositing

Hudson and James Bays 24 February 2000

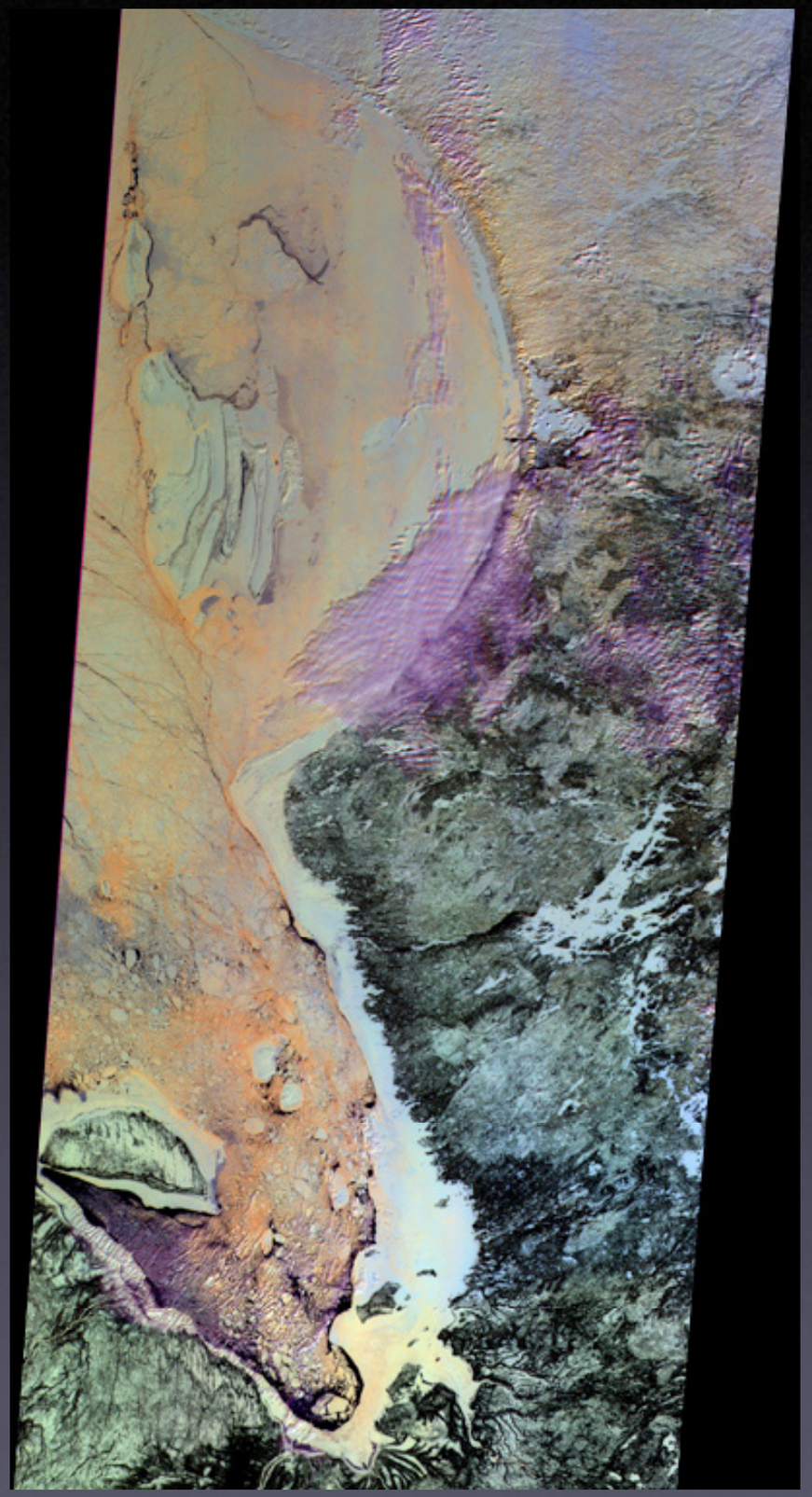


Image Grand Tour (IGT)

- Symanzik et al. (2002); Wegman, Poston, and Solka (1998); Wegman (1992).
- Project multi-channel image data down to a 1-d subspace.
- Produce an image (gray-scale) of projected values.
- Repeat with a randomly driven, space-filling selection of projections.
- But... what do the projections mean?

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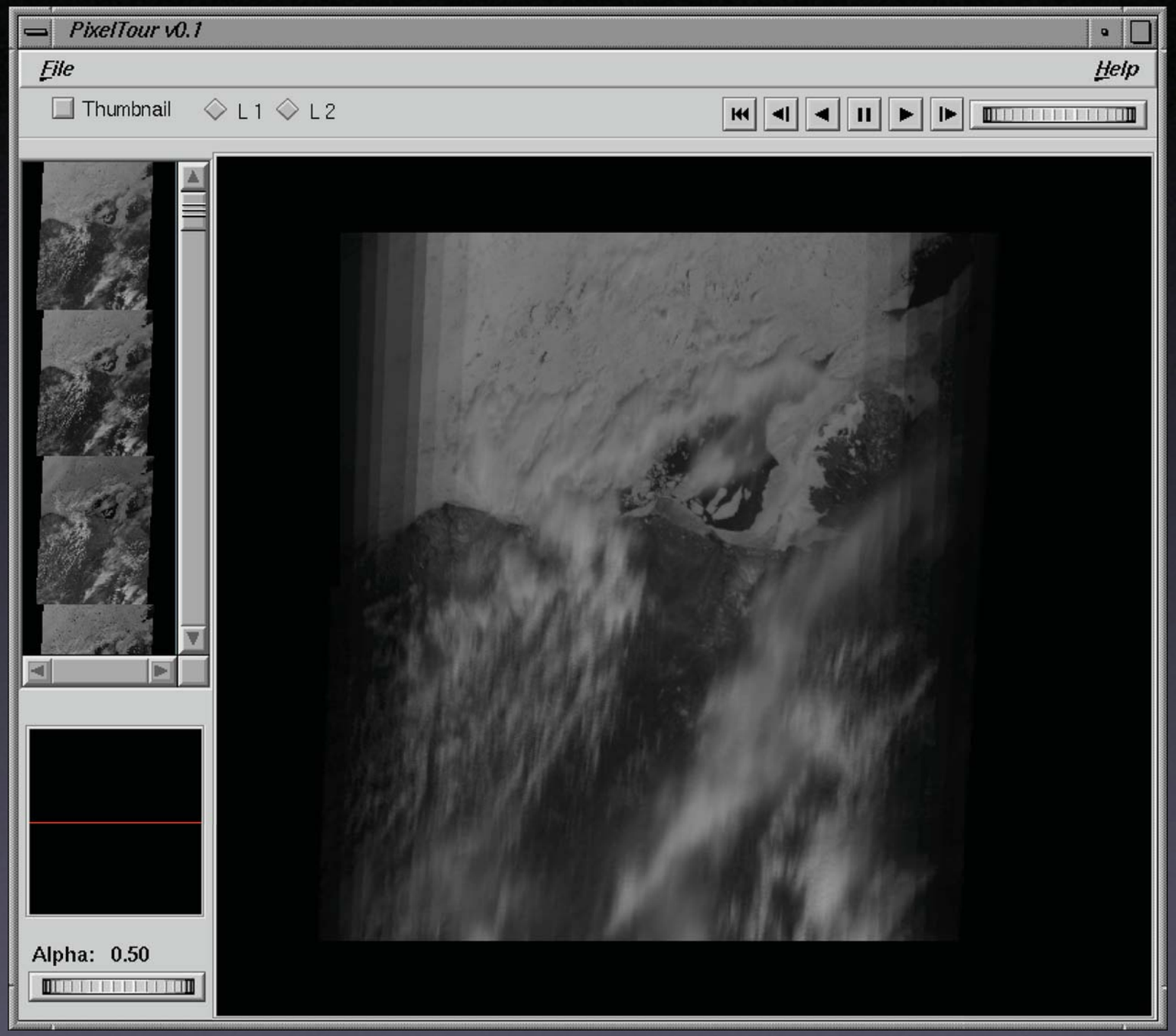
Image Grand Tour (IGT)



New Image Grand Tour

- Project multi-channel image data down to a 3-d subspace spanned by PC1, PC2, PC3.
- Produce an image (rgb) of projected values.
- Repeat with a sequence of projections rotating in increments of θ from PC1, PC2, PC3 to PC2, PC3, PC4, to PC3, PC4, PC5, etc.
- Cycling from “low-frequency” to “high-frequency” information.

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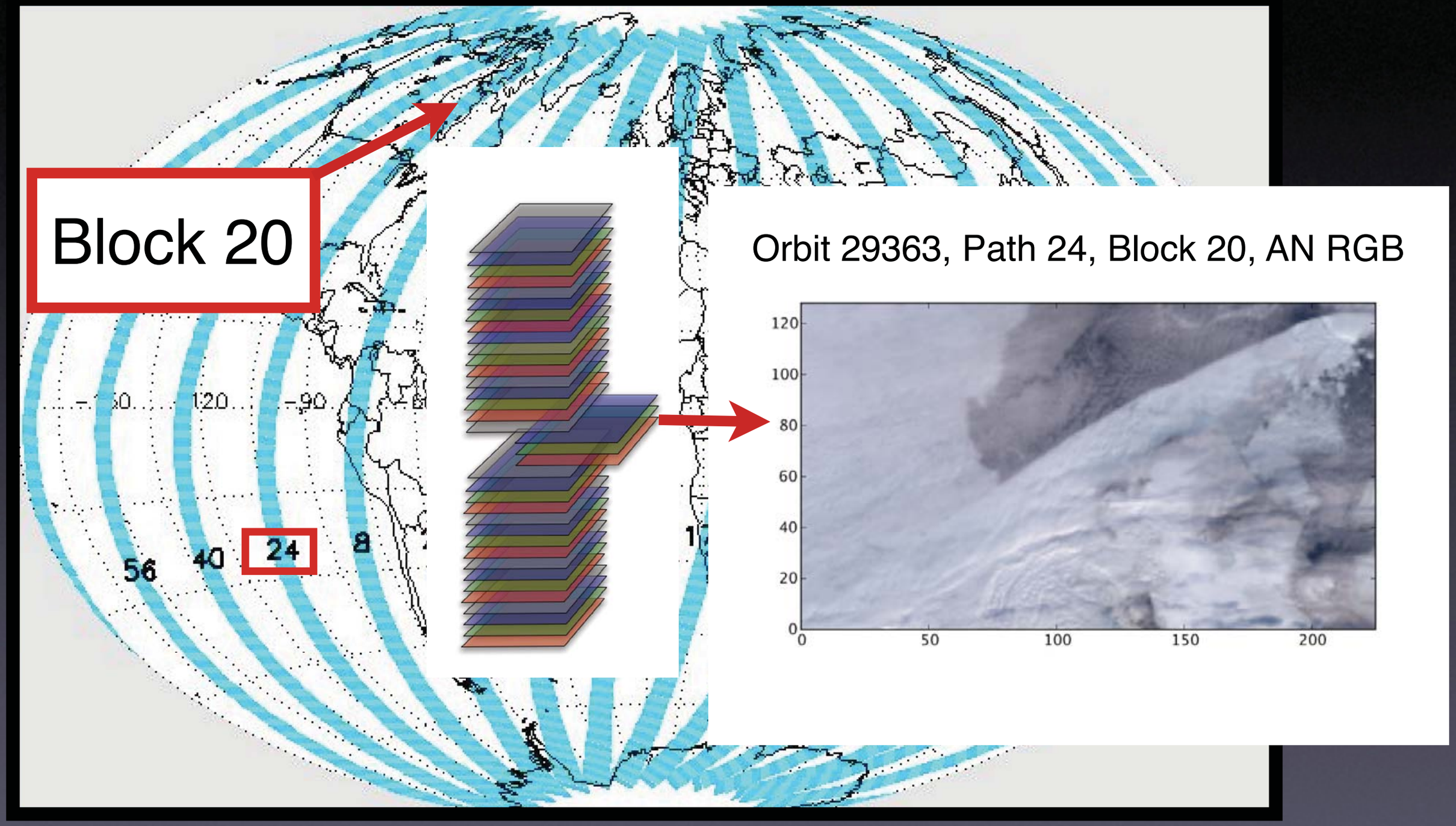
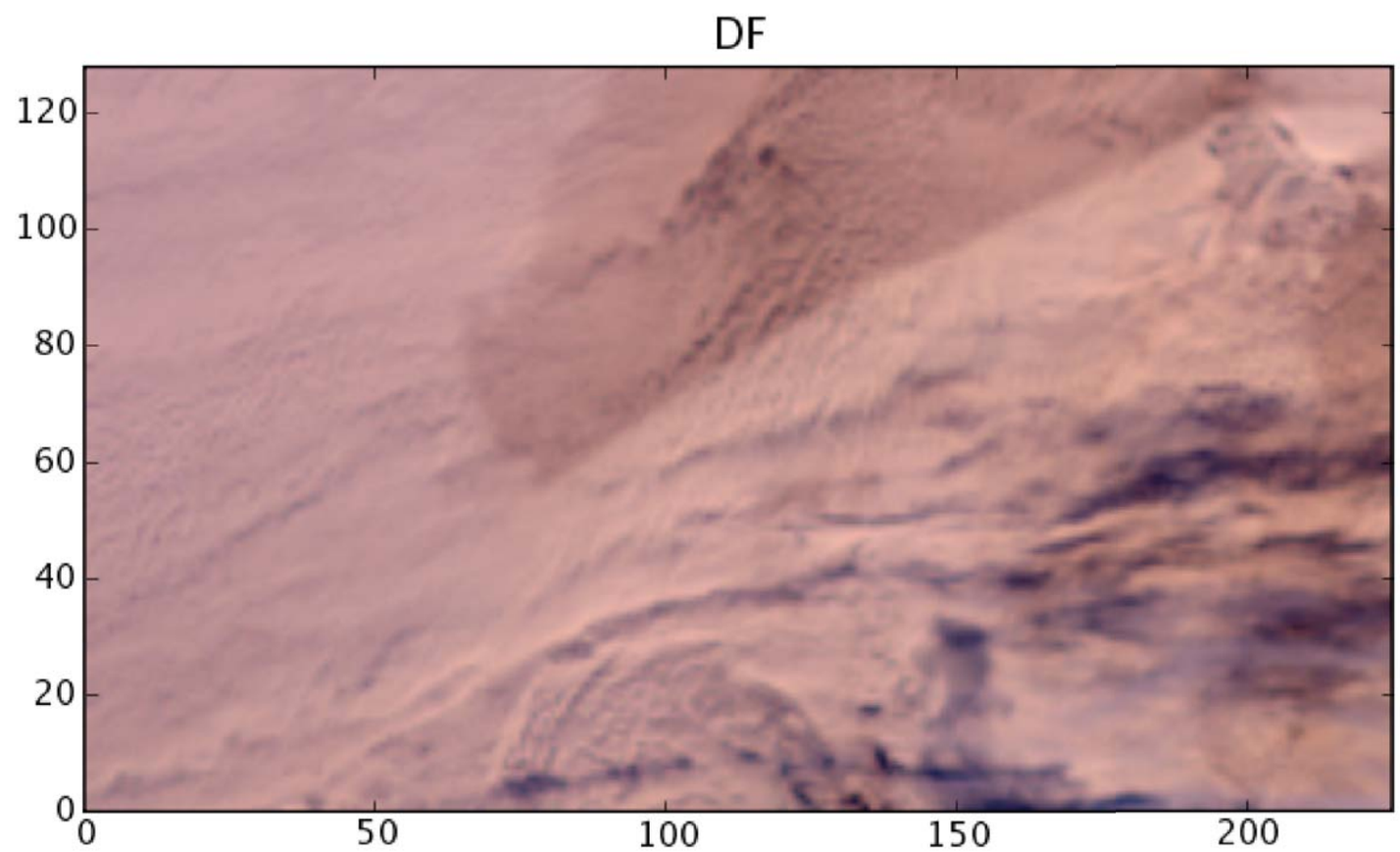
Multiangle Imaging SpectroRadiometer



Multiangle Imaging SpectroRadiometer



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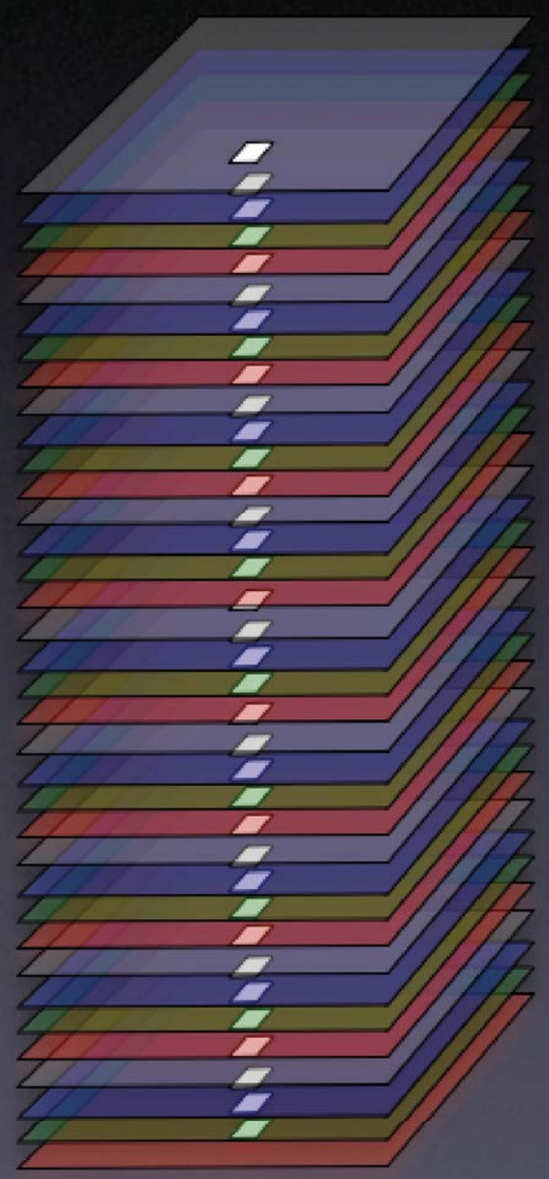
Methodology



36 dimensional data vector corresponding to pixel at line l and sample s :

$$\mathbf{x}_{ls} = (x_{ls1}, x_{ls2}, \ldots, x_{ls36})'$$ (assume $\mathbf{x}_{ls}$ is centered)

$$\mathbf{\Sigma} = (LS)^{-1} \sum_{l=1}^{L} \sum_{s=1}^{S} \mathbf{x}_{ls} \mathbf{x}_{ls}'$$

Let $\mathbf{e}_1, \mathbf{e}_2, \ldots, \mathbf{e}_{36}$ be the eigenvectors of $\mathbf{\Sigma}$.

$$\mathbf{y}_{ls} = \mathbf{x}_{ls}' \mathbf{E}_{123} \qquad \mathbf{E}_{123} = [\mathbf{e}_1 | \mathbf{e}_2 | \mathbf{e}_3]$$

projection of $\mathbf{x}_{ls}$ into the 3-d subspace spanned by $\mathbf{e}_1, \mathbf{e}_2, \mathbf{e}_3$.

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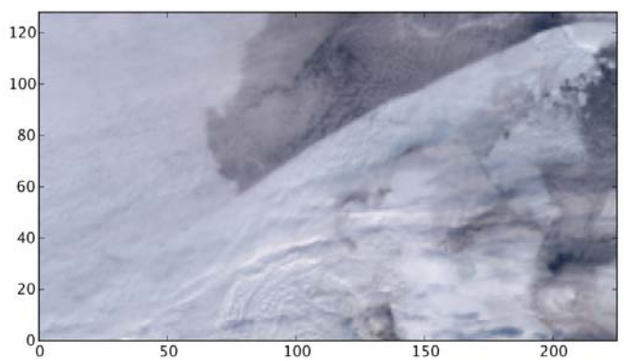
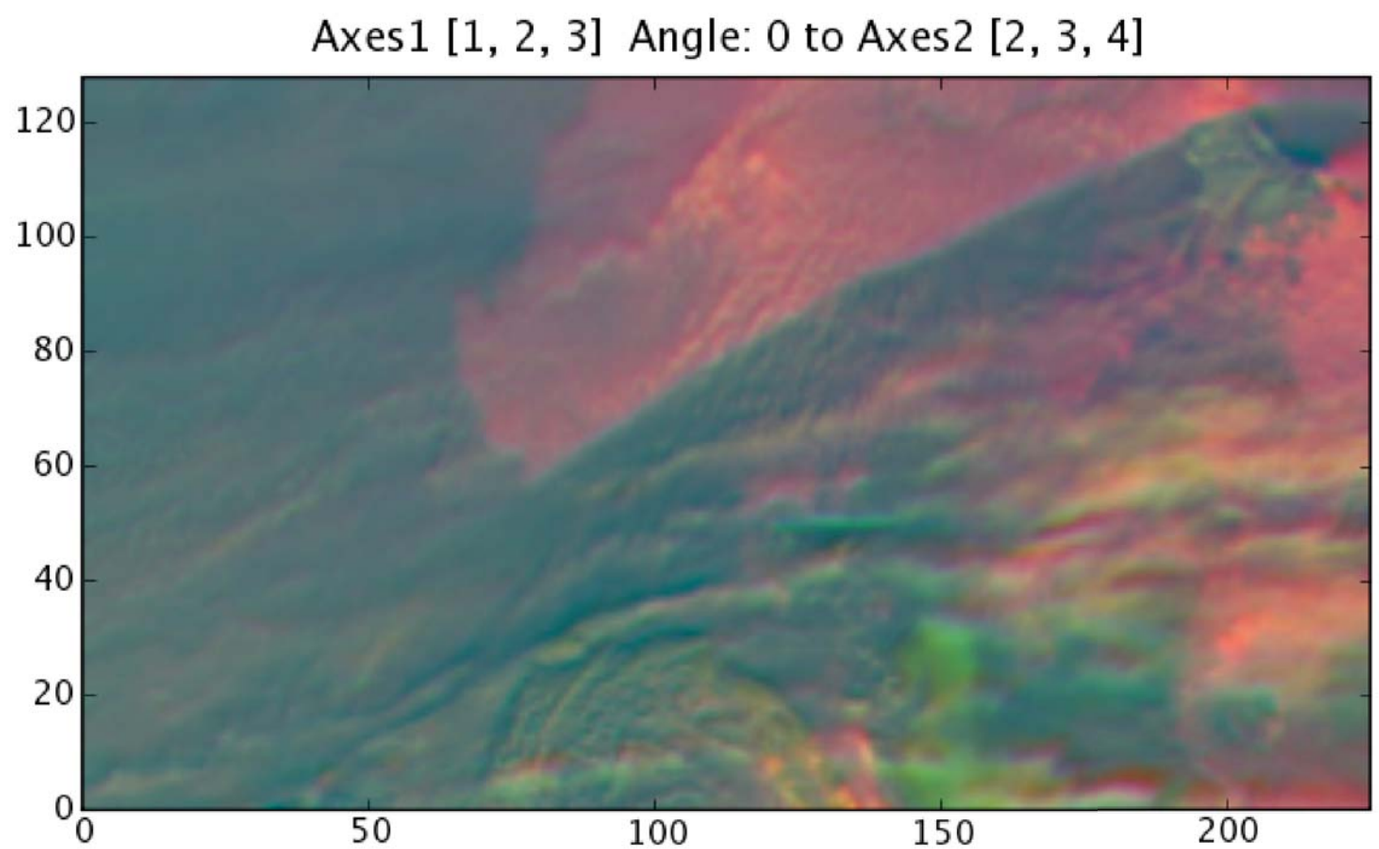
Methodology

(Note: zero-based indexing here)

$$\mathbf{y}_{ls} = (y_r, y_g, y_b)'$$



Orbit 29363, Path 24, Block 20, [PC1,PC2,PC3]



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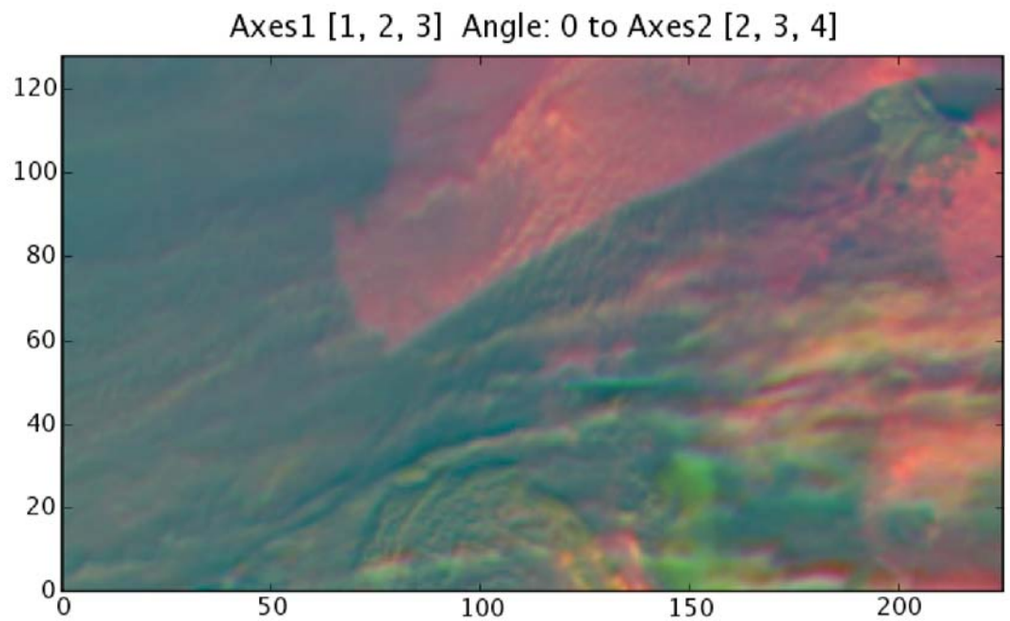
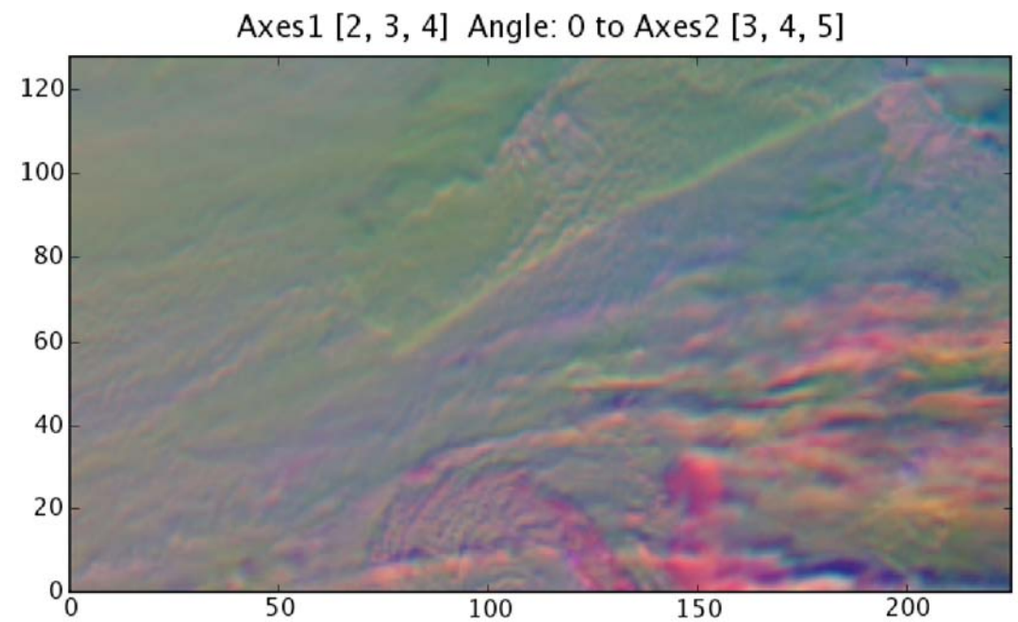
Methodology

PC1,PC2,PC3



PC2,PC3,PC4



How to move “smoothly” ?

Methodology

Rotation matrix: rotate axis a θ° in the direction of axis b.

$$R_{a,b}(\theta) = \begin{cases} r_{ii} & = & 1, & i \neq a, i \neq b, \\ r_{aa} & = & \cos\theta, & \\ r_{bb} & = & \cos\theta, & \\ r_{ab} & = & -\sin\theta, & \\ r_{ba} & = & \sin\theta, & \\ r_{ij} & = & 0 & elsewhere \end{cases} \quad : \quad r_{ij}$$

$$\left.\begin{array}{l} \text{Apply } R_{12}(\theta) \text{ to } \mathbf{e}_1, \\ \text{Apply } R_{23}(\theta) \text{ to } \mathbf{e}_2, \\ \text{Apply } R_{34}(\theta) \text{ to } \mathbf{e}_3 \end{array}\right\} \quad R_{12}(\theta)R_{23}(\theta)R_{34}(\theta)E_{123} = P$$

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Methodology

Algorithm:

$i = 1, j = 2, k = 3$ — i, j, k indexes PC_i, PC_j, PC_k

while $k \leq 36$:

$E = E_{ijk}$ — E_{ijk} 3 eigenvectors of Σ

$t = 0$ — t is step

while $\theta < 90$:

$\theta = 2t$

$P = R_{ij}(\theta) R_{jk}(\theta) R_{k,k+1}(\theta) E_{ijk}$

for $l = 1, L$:

l, s indexes pixel

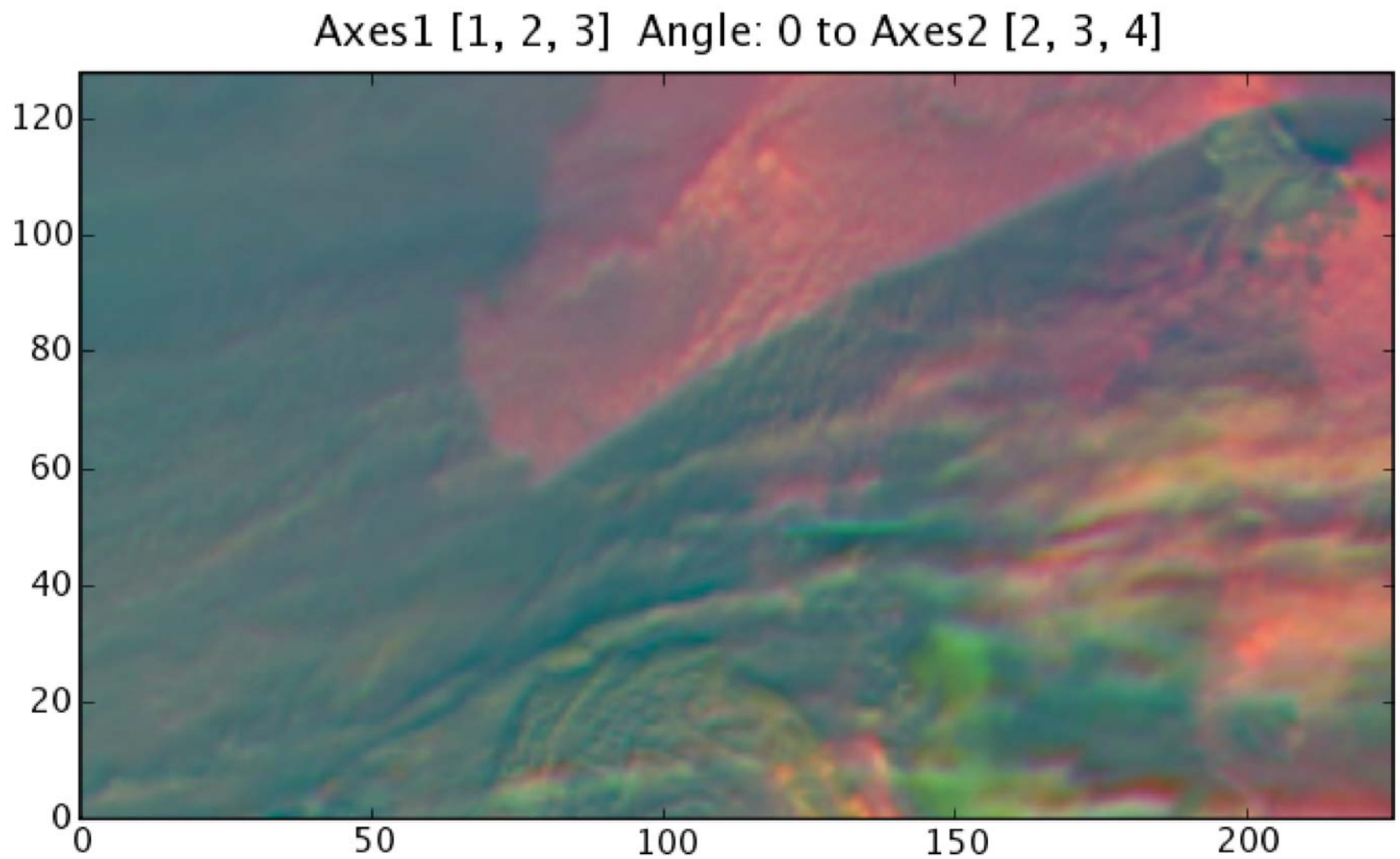
for $s = 1, S$:

$\mathbf{y}_{ls}^{(t)} = \mathbf{x}' P$ — $\mathbf{y}_{ls}$ is projected rgb

$t = t + 1$

$i = j, j = k, k = k + 1$

Results


Axes1 [1, 2, 3] Angle: 0 to Axes2 [2, 3, 4]
120
100
80
60
40
20
0
0
50
100
150
200

Conclusions

- Modified Image Grand/Guided Tour discriminates among different physical regimes in MISR multiangle, multispectral data.
- Different types of surfaces and clouds distinguished.
- How to characterize relationships between spatial locations and data values?
- Future: test on different scenes and data sets.

Thanks to the MISR Project and Team!