The Landsat Data Continuity Mission

AN INCREASED POTENTIAL FOR THE LANDSAT DATA CONTINUITY MISSION TO CONTRIBUTE TO WATER QUALITY STUDIES FOR INLAND, CASE 2 WATERS

Aaron Gerace

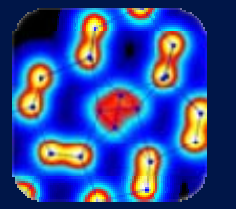
John R. Schott

Sponsored

by

United States Geological Survey

Digital Imaging and Remote Sensing Laboratory



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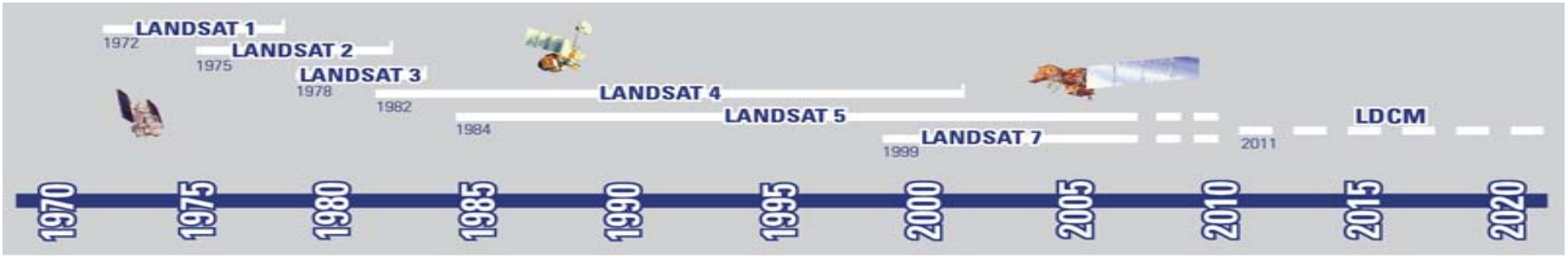
The Landsat Data Continuity Mission



True Color Composite

Thermal Channel

Water is Unique!

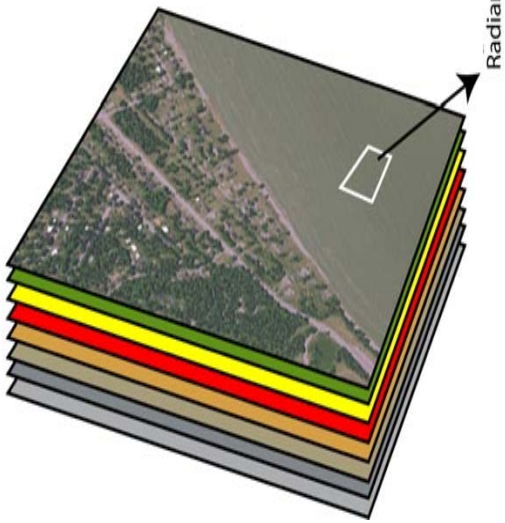
Atmosphere
to Sensor

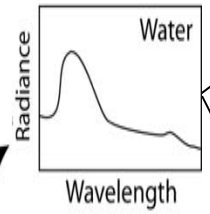
Air/Water Transition

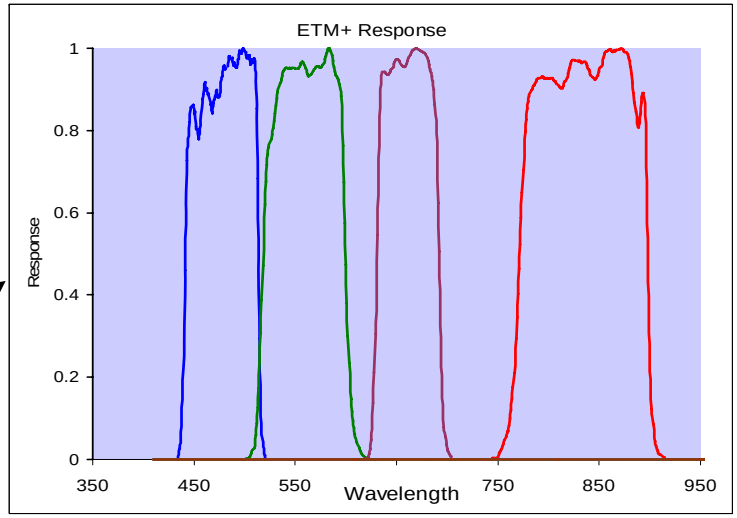
Water/Air Transition

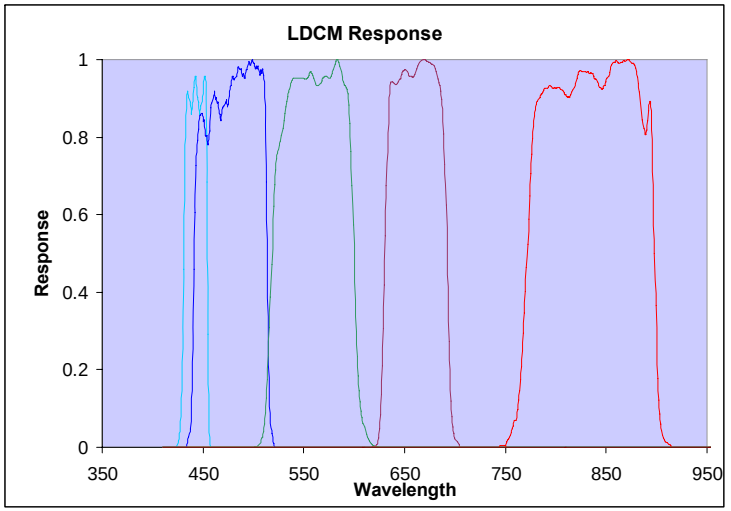
In Water

LDCM Features: Response

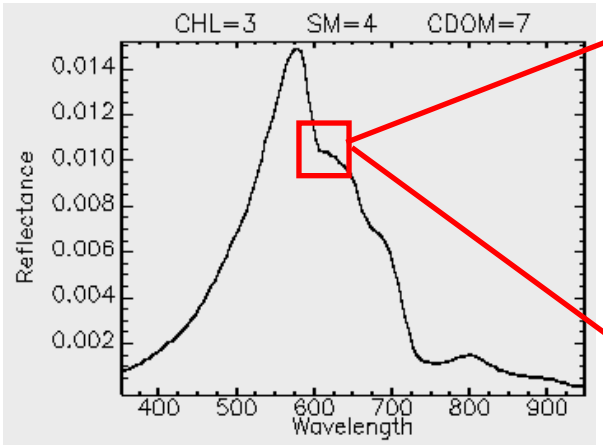




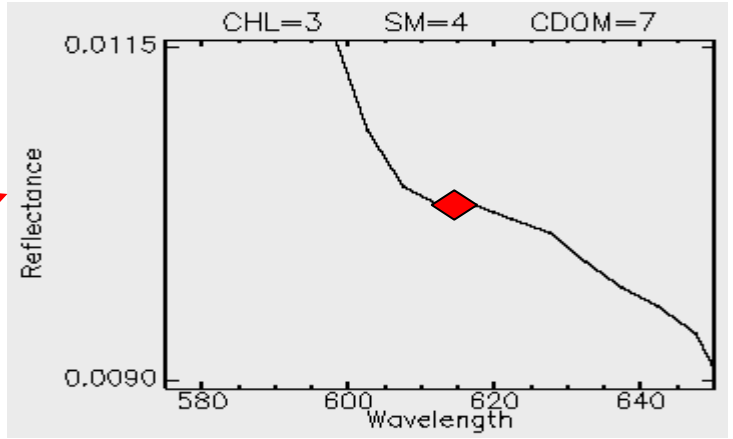




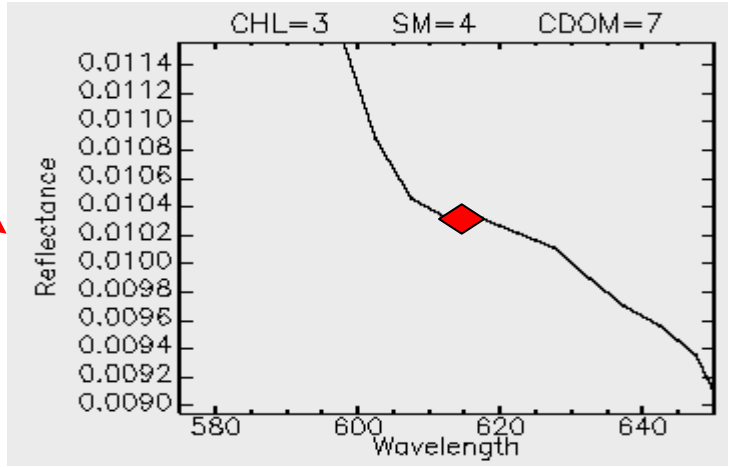
LDCM Features: Quantization



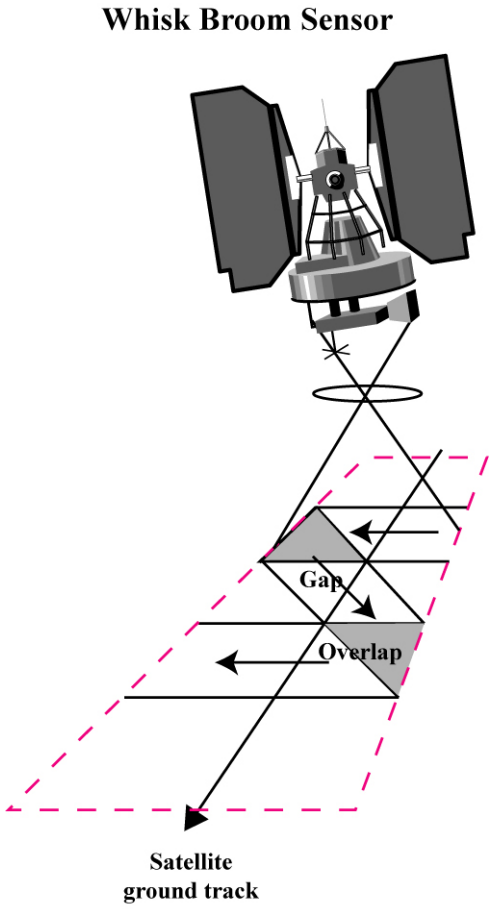
ETM+

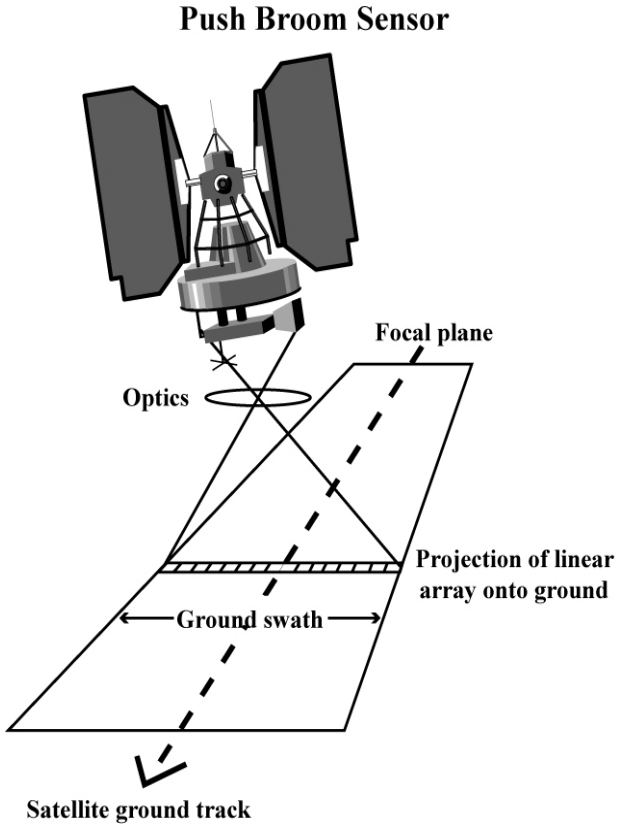


LDCM



LDCM Features: Signal to Noise





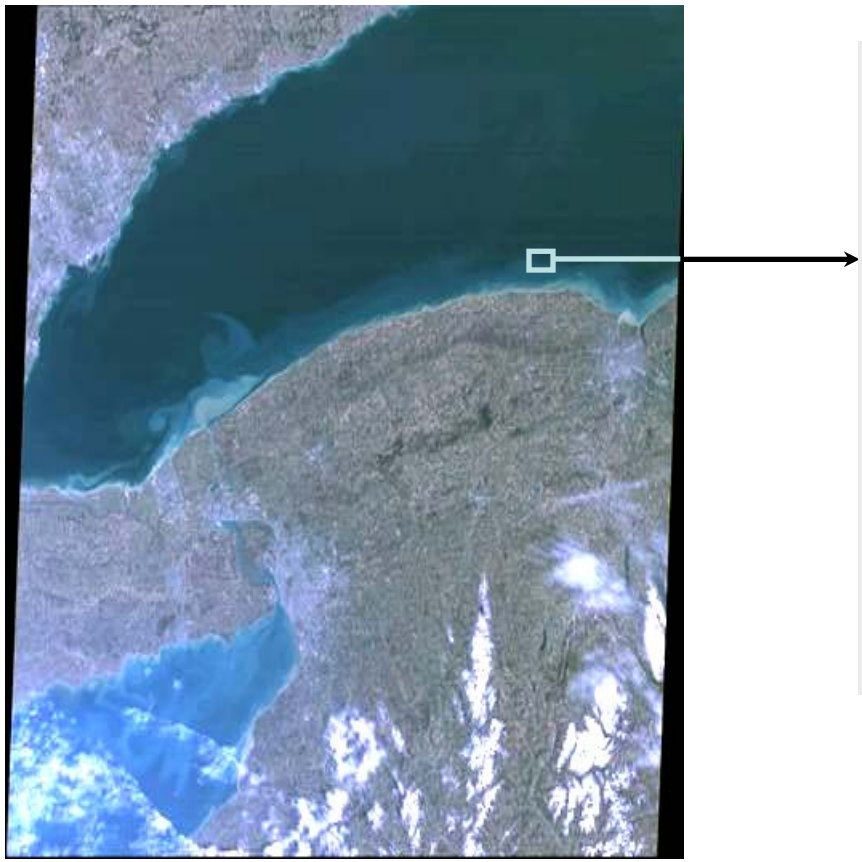
Modeling LDCM Improvements

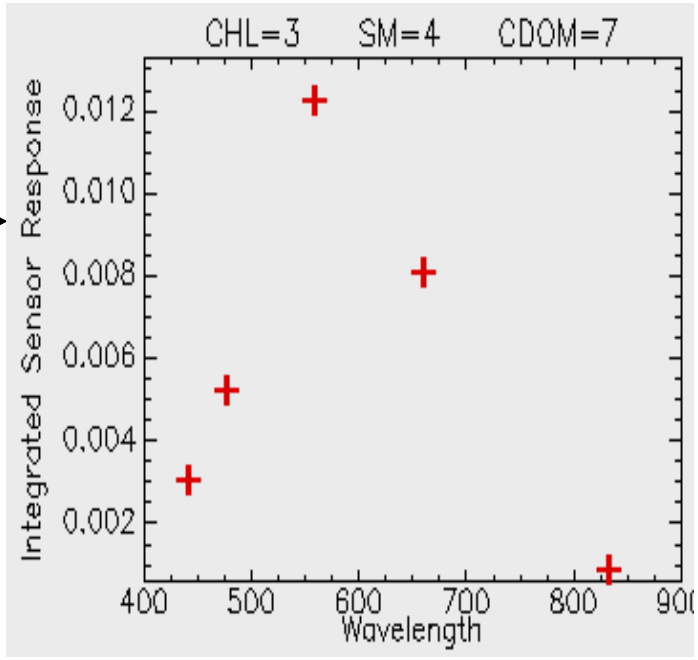
What do we gain from the addition of …

- an Aerosol Blue band
- 12 bit quantization
- Improved signal-to-noise ratios

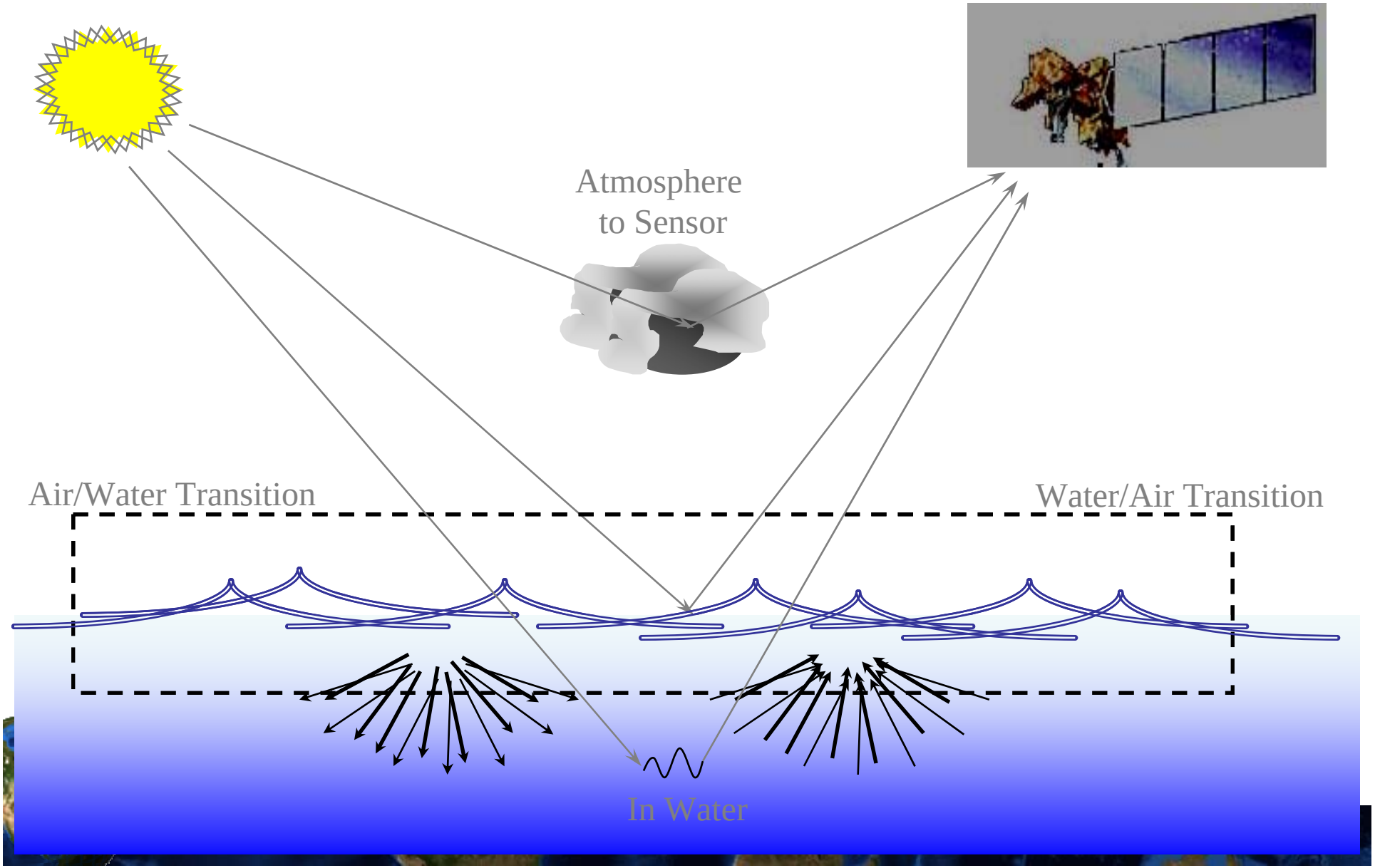
- **Can LDCM be effective in the constituent retrieval process? (perfect atm. comp.)**
- **Can we compensate for the atmosphere?**
- **Can we compensate for the lack of a thermal band?**

Modeling the Process

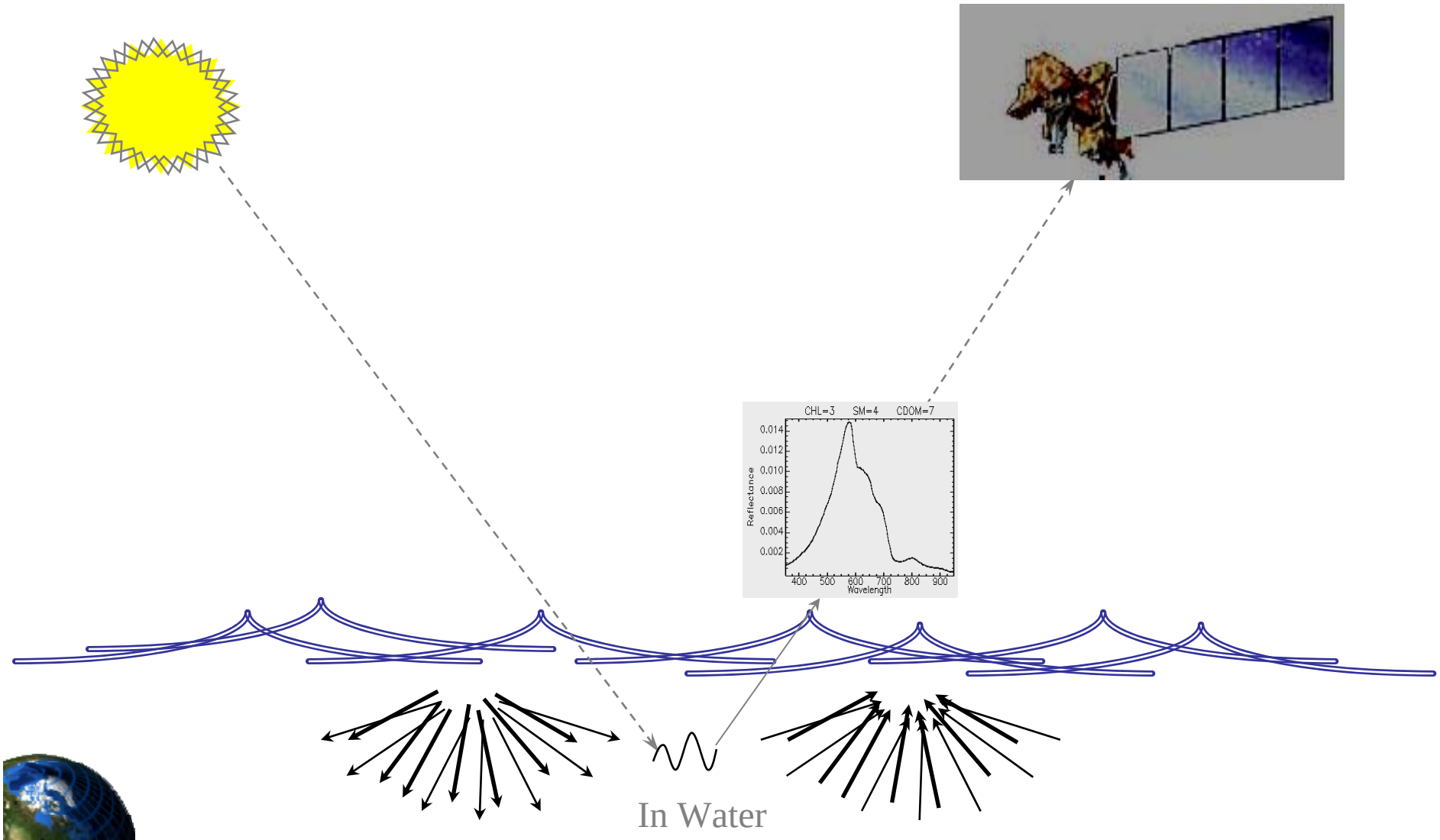




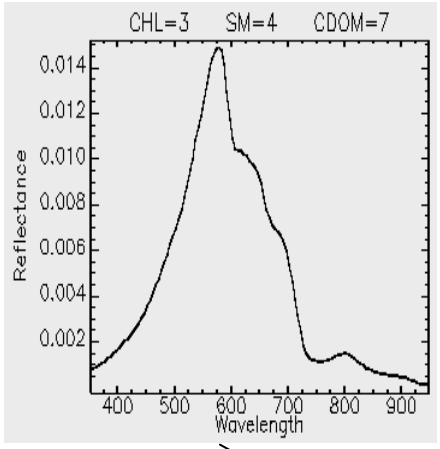
Modeling the Process

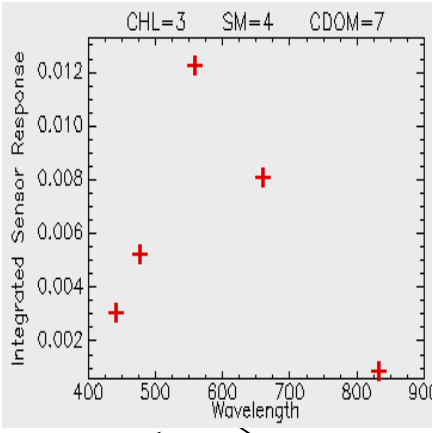


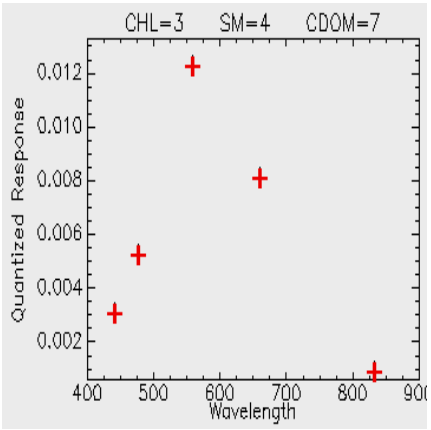
Modeling the Process: Hydrolight



Modeling the Process: The Sensor



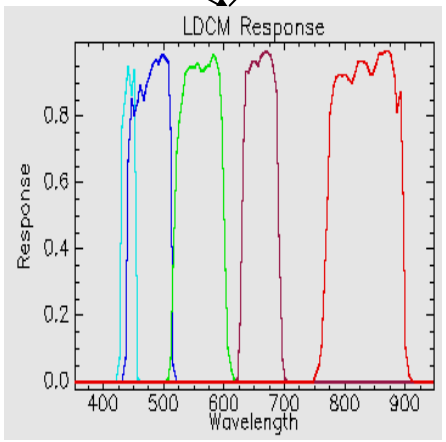


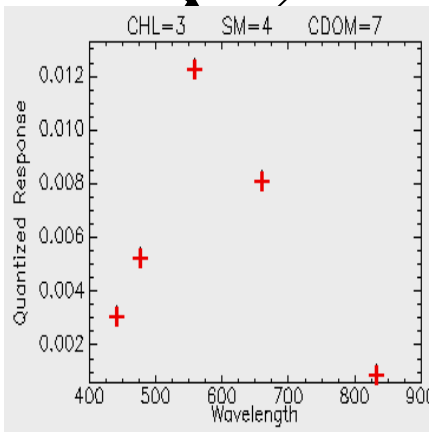


Spectrally Sample Signal

Add Sensor Noise

Quantize Signal



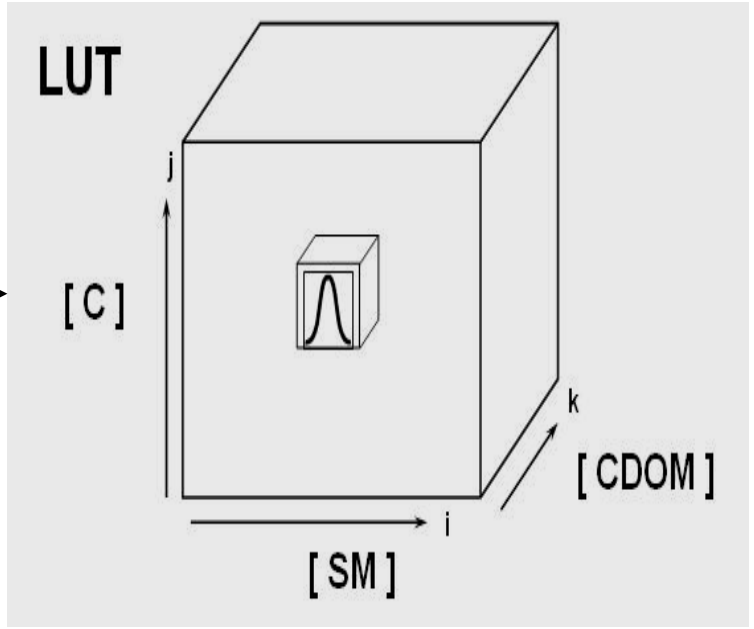


Modeling the Process: The Scene

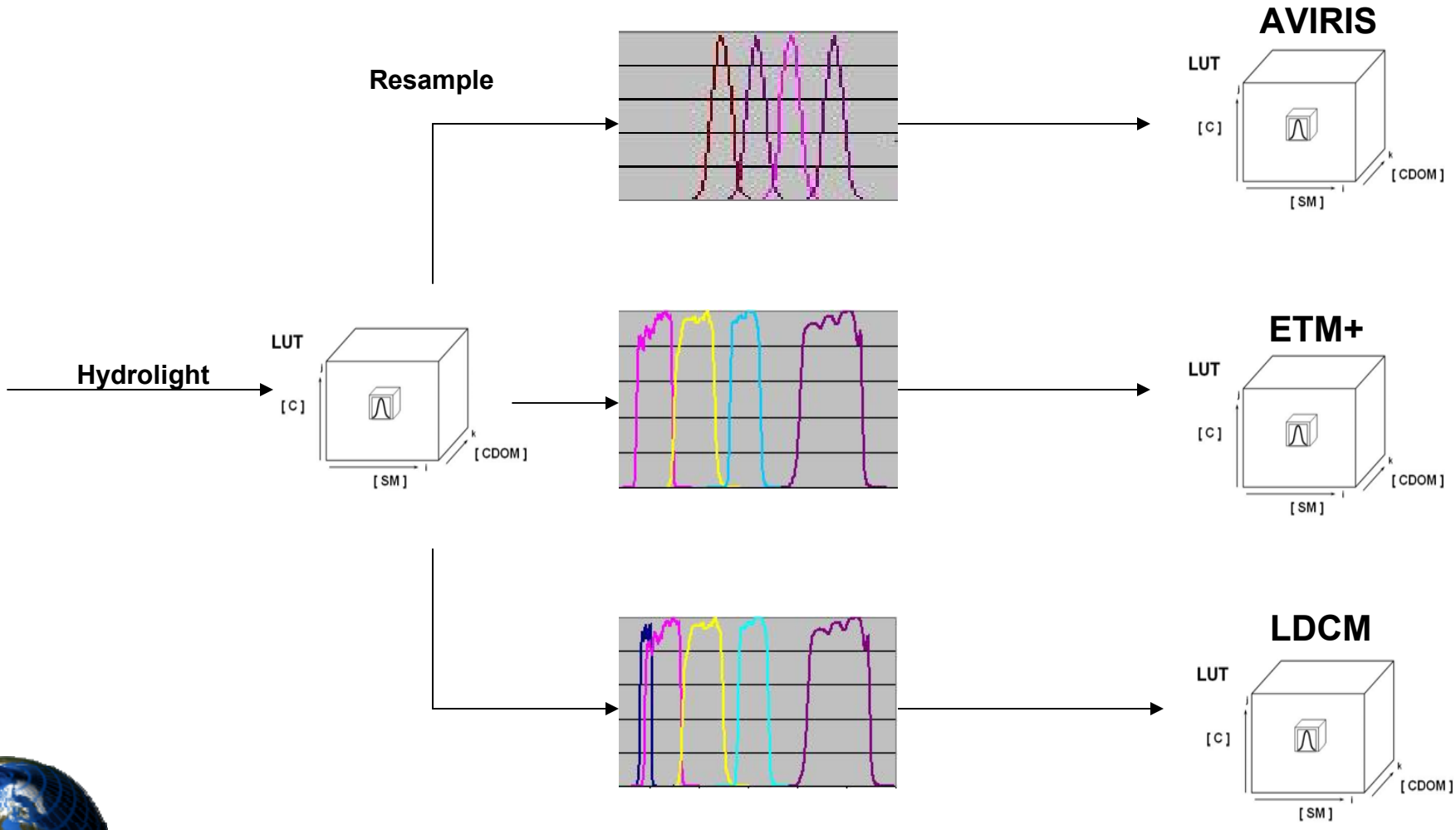
LUT Development

C	SM	CDOM
0	0	0
.5	.5	.5
1	1	.75
3	2	1
5	4	2
7	8	4
12	10	7
24	14	10
46	20	12
68	24	14

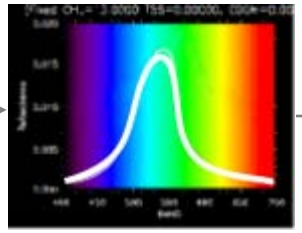
Hydrolight



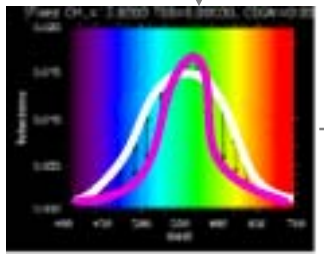
LUT Development



Amoeba Process

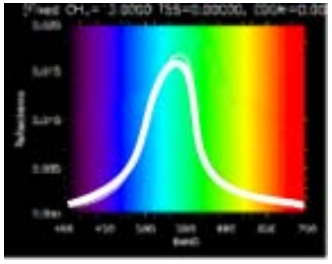


λ



S_Q Error

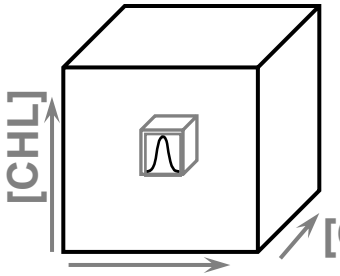
TRUE



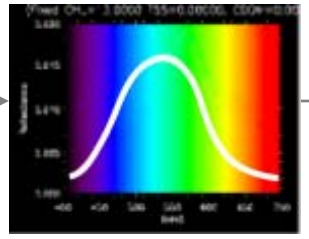
$\min [(S_T - S_P)^2]$

FALSE

LUT

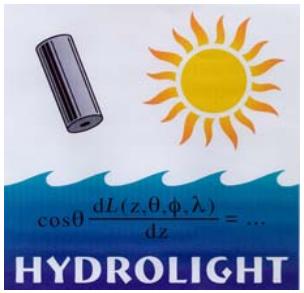


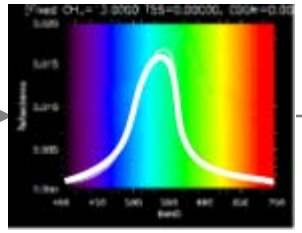
[CHL] [SM] [CDOM]



S_p predicted

Amoeba Process





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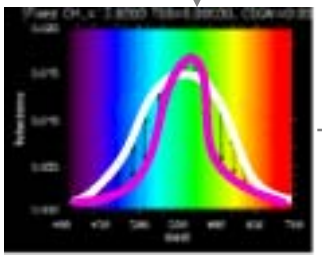
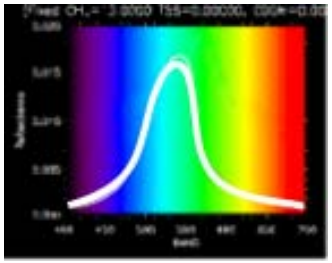


S_Q Error

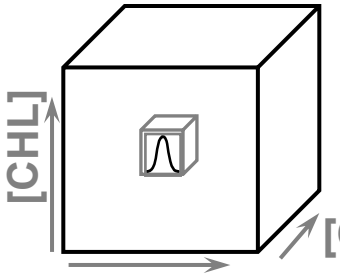
TRUE



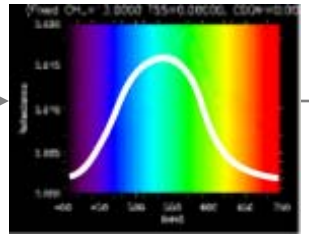
$\min [(S_T - S_P)^2]$

FALSE

LUT

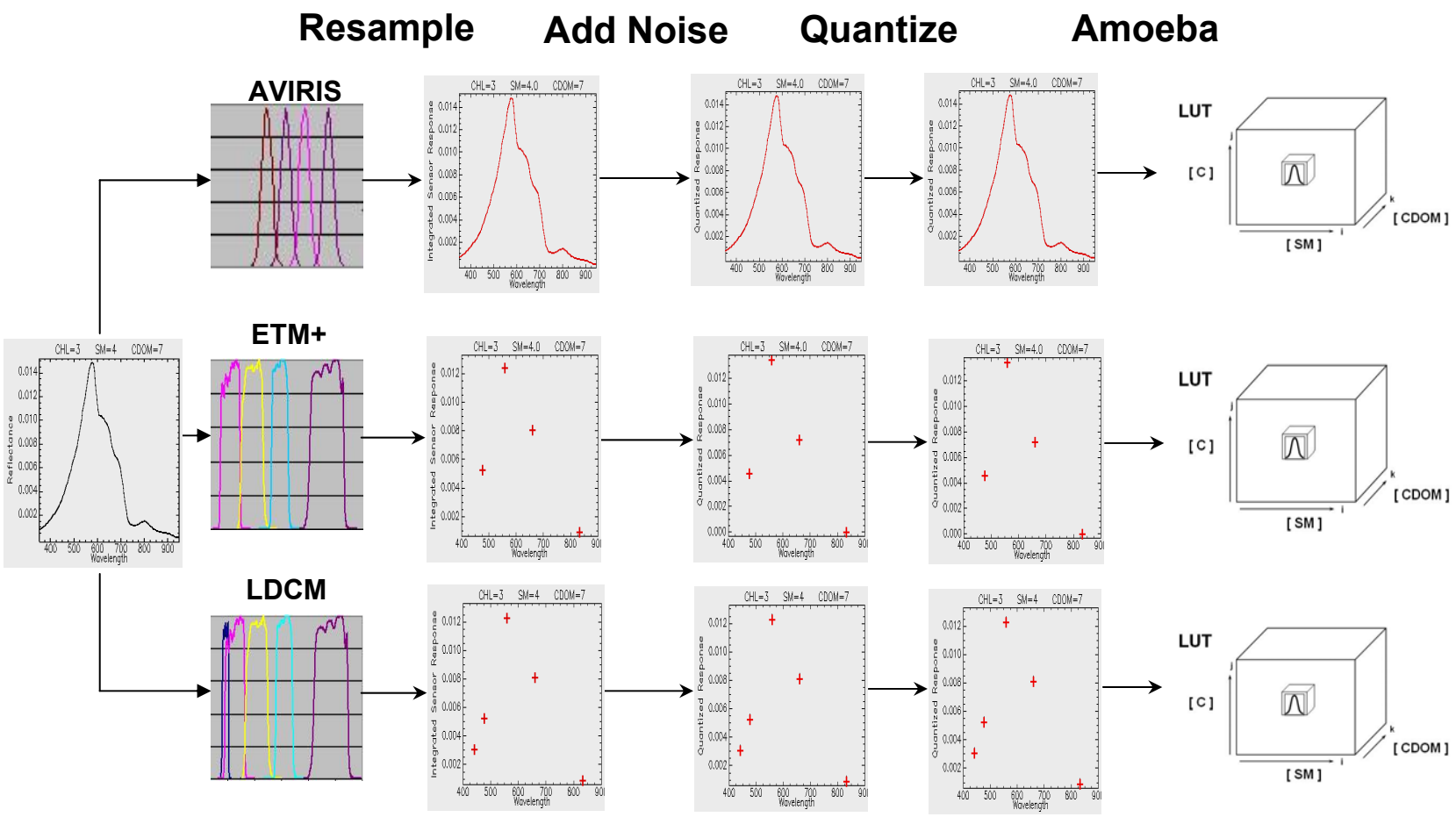


[CHL] [SM] [CDOM]



S_p predicted

Process Summary



RMS of Residual Errors

	CHL(μg/L)	SM(mg/L)	CDOM(1/m)
AVIRIS	.5	.1	.1
ETM+	.5	.6	.2
LDCM	.5	.5	.1

RMS of Residual Errors

	CHL(μg/L)	SM(mg/L)	CDOM(1/m)
AVIRIS	.5	.1	.1
ETM+	.5	.6	.2
LDCM	.5	.5	.1
ETM+ Quantized	5.7	2.8	1.7
LDCM Quantized	1.2	.6	.2
ETM+ Noise & Quantized	7.4	4.8	3.2
LDCM Noise & Quantized	3.7	1.2	.9

RMS of Residual Errors… (As Percentages)

10% Goal

	CHL(μg/L)		SM(mg/L)		CDOM(1/m)	
AVIRIS	.5		.1		.1	
ETM+	.5		.6		.2	
LDCM	.5		.5		.1	
ETM+ Quantized	5.7	8.4%	2.8	11.7%	1.7	12.1%
LDCM Quantized	1.2	1.8%	.6	2.5%	.2	1.4%
ETM+ Noise & Quantized	7.4	10.9%	4.8	20.0%	3.2	22.9%
LDCM Noise & Quantized	3.7	5.4%	1.2	5.0%	.9	6.4%

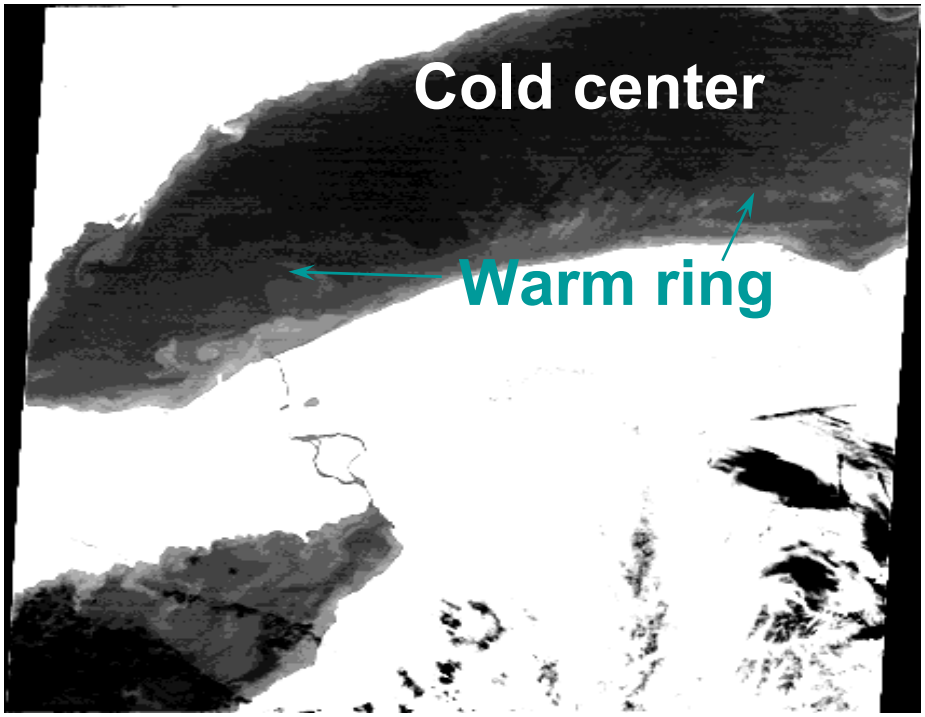
Conclusions

- **Blue band contributes to retrieval of suspended materials.**
- **12 bit quantizer and improved SNR of LDCM significantly improves our ability to perform constituent retrieval.**
- **LDCM exhibits the potential to be a valuable tool in the constituent retrieval process.**

Future Work

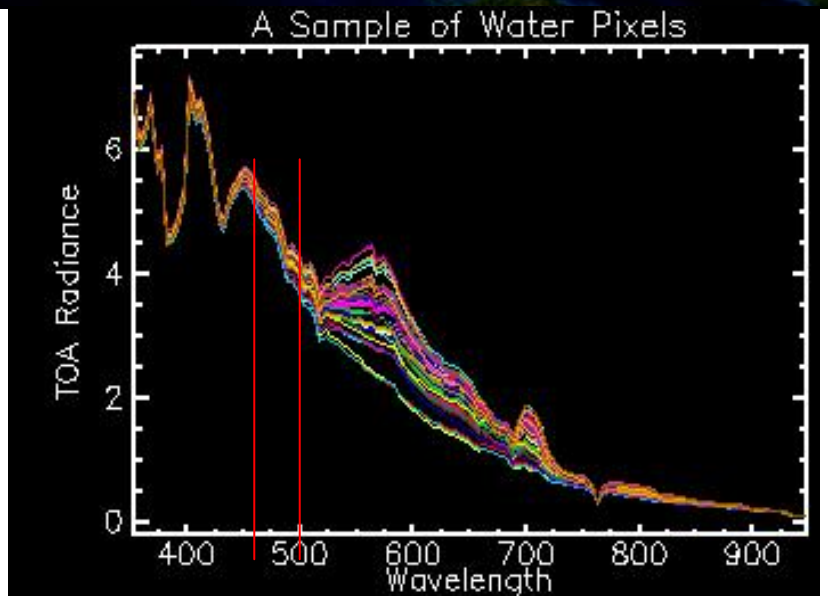
True Color Composite

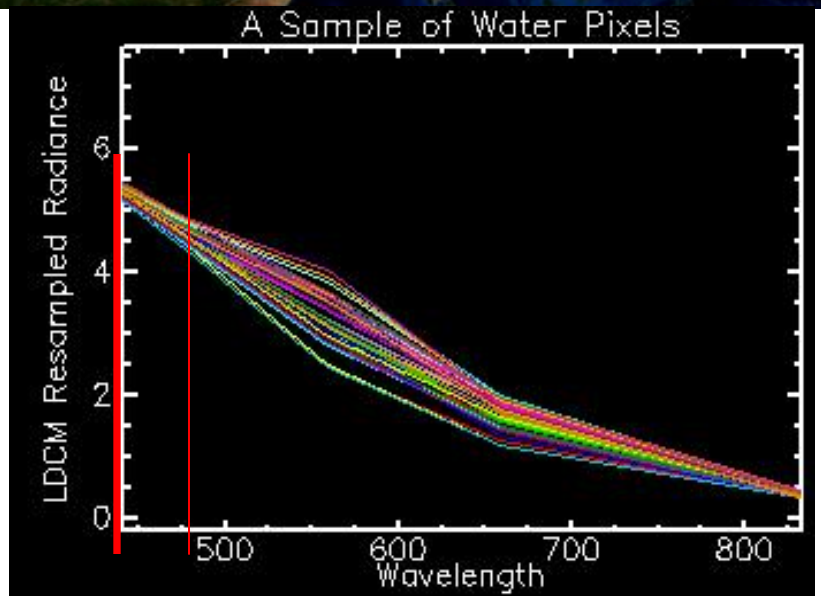
Thermal Channel



- How important is blue band for atmosphere correction?
- Role of thermal band in predicting hydrodynamics of receiving water.

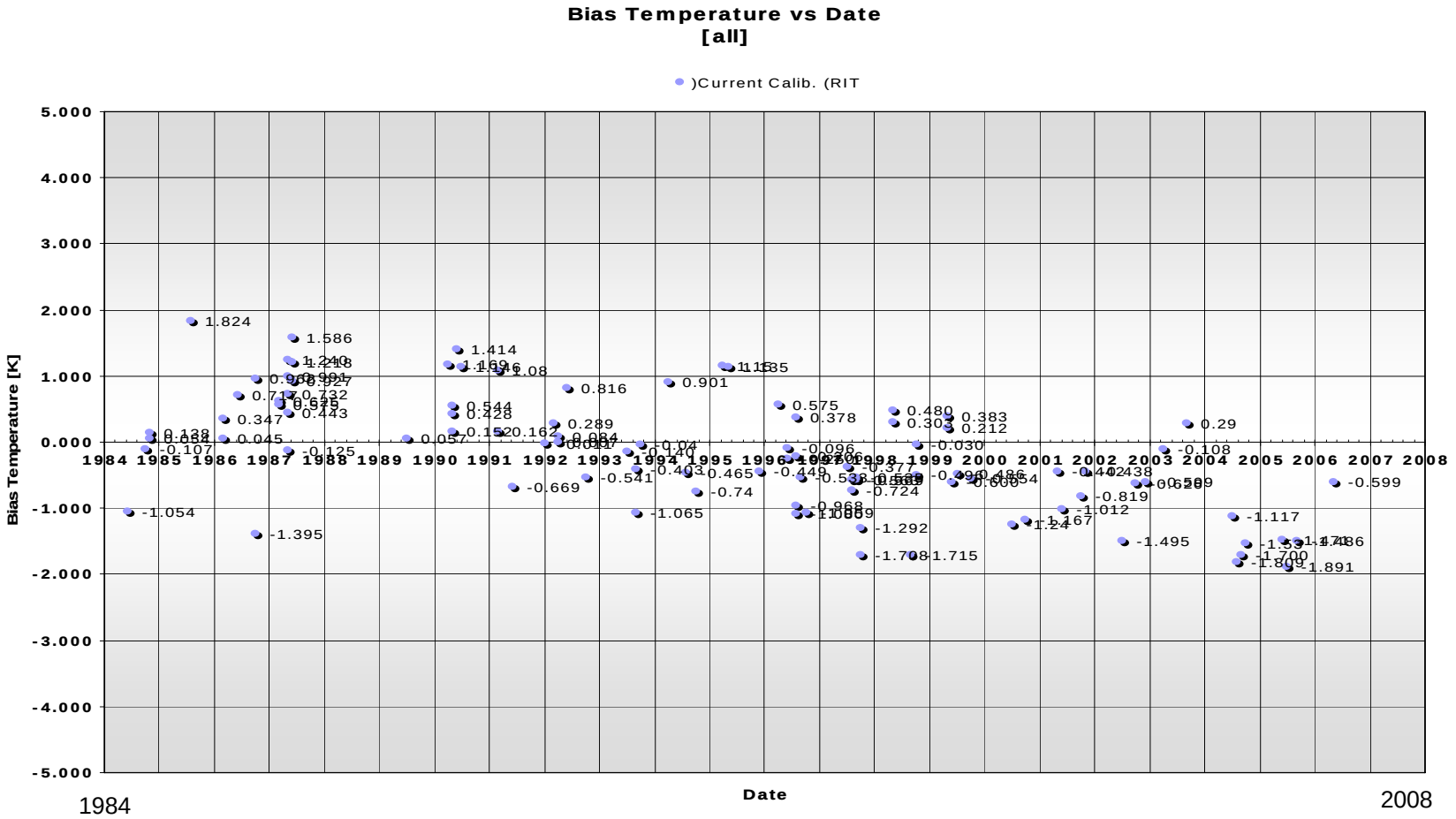
Hydrolight-generated water pixels as seen through a 40km visibility atmosphere.





- (Left) TOA Radiance, (Right) Resampled to five LDCM bands.
- Atmospheric compensation algorithm developed to take advantage of deep blue band.
  - Notice low variability at 443nm and increased variability at 482nm.
  - Correction algorithm takes ratio of 443 band and 865 band based on the assumption that variability in these bands is due solely to atmosphere.
  - This assumption breaks down for 482 band as variability due to water signal increases.

Calibration Curve: Filtered



Landsat 5 Calibration History

R·I·T

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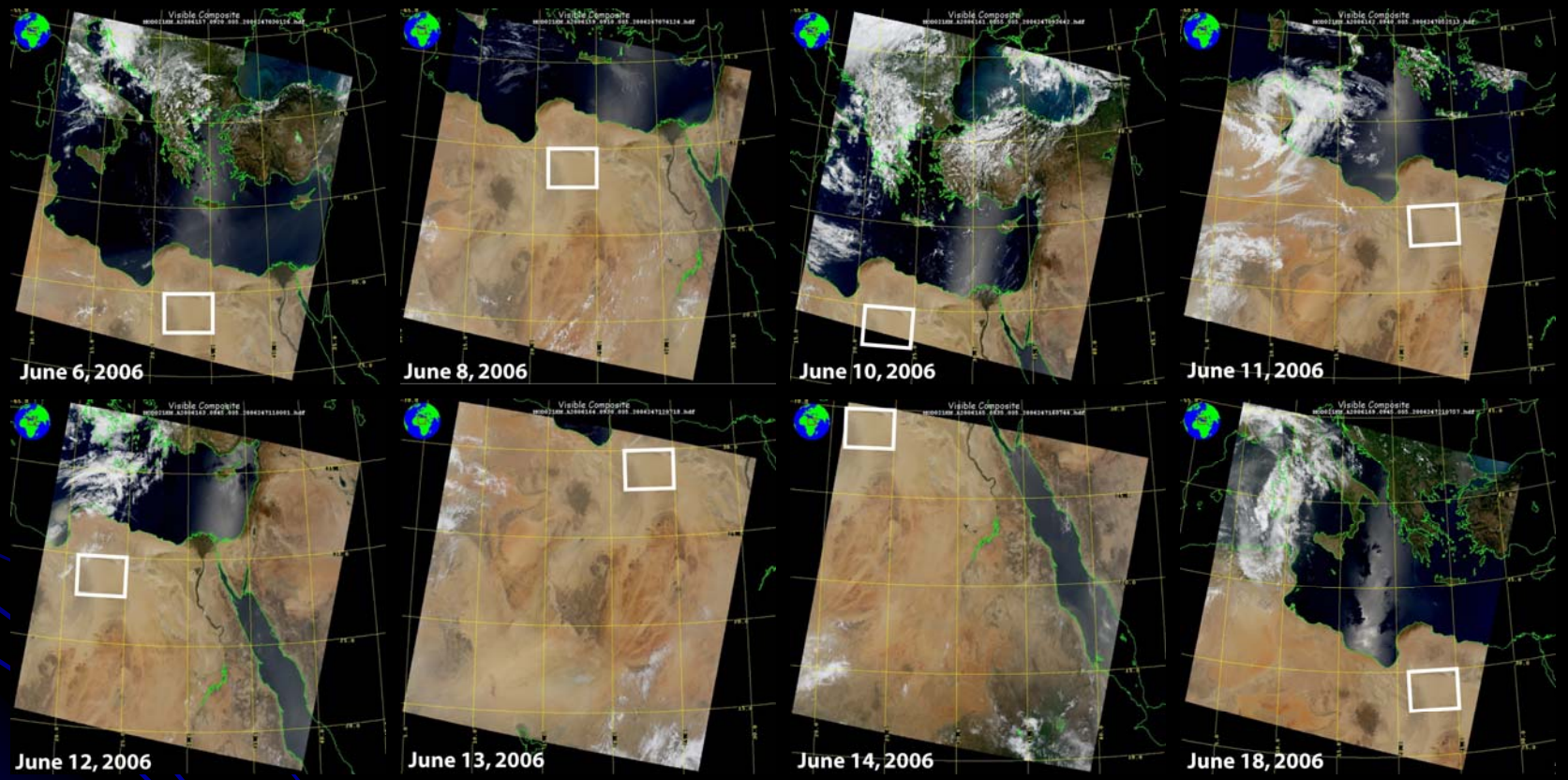

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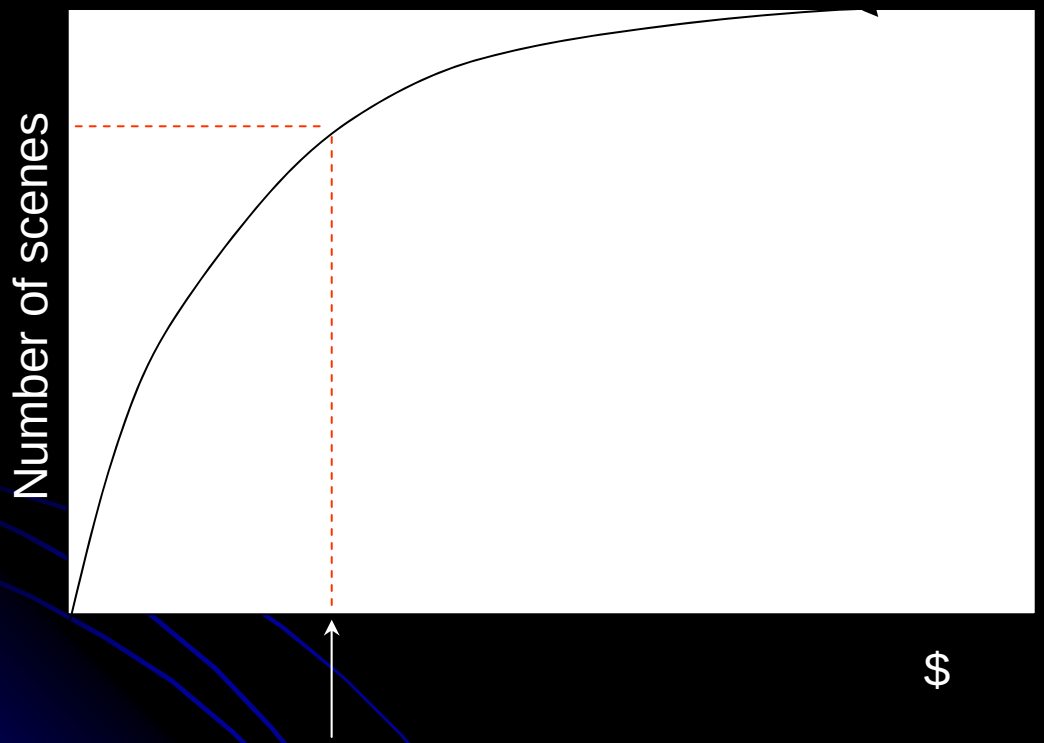
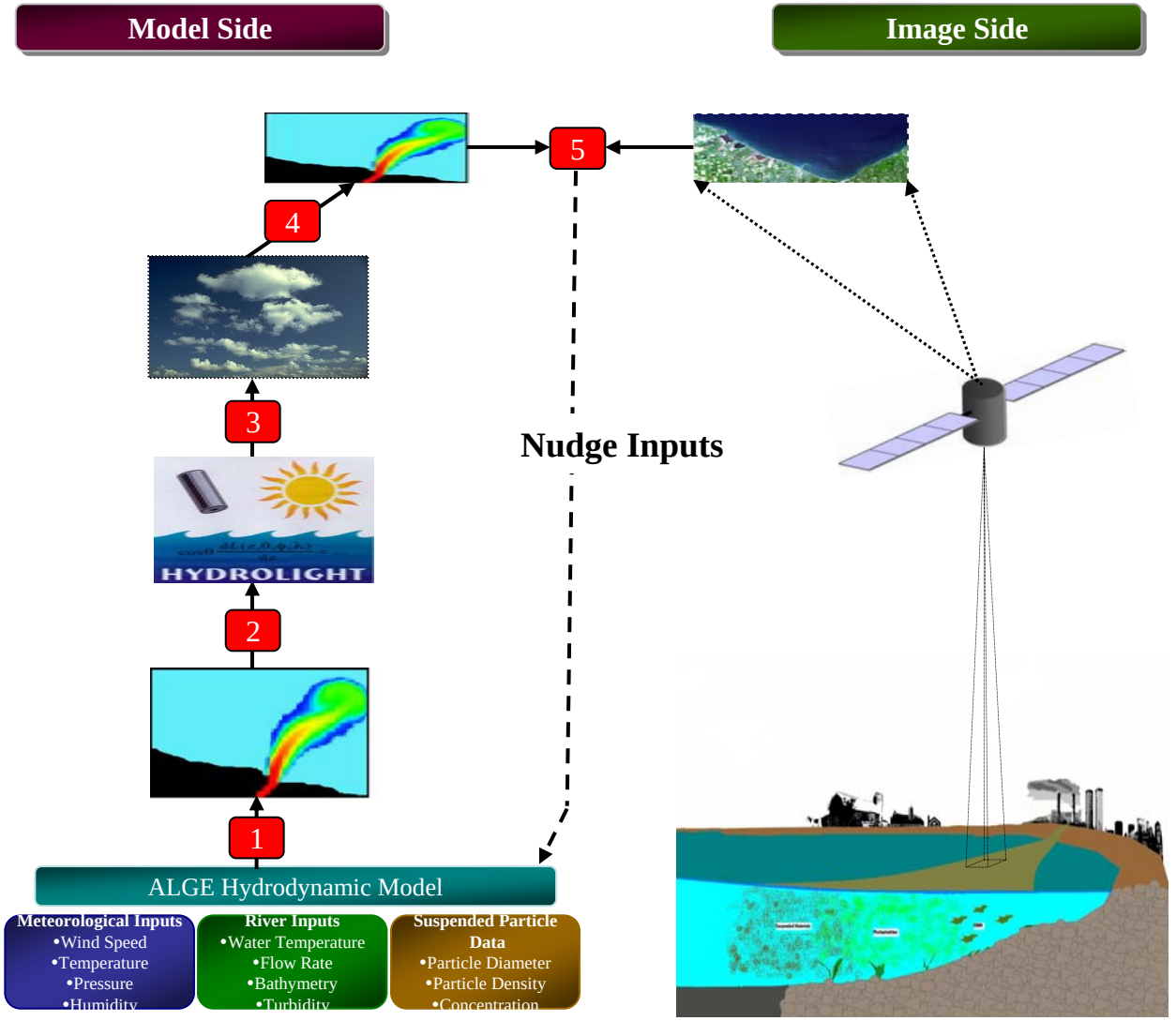
Center for Imaging Science

International Archive Guestion



80% Solution vs. Cost of new Mission(s) →

Using Remotely Sensed Data for Model Calibration



Performed constituent retrieval on real data (Genesee Plume) to test algorithm

- Ran algorithm with 482nm and 865nm bands of ETM+.
- Ran algorithm with 442nm and 865nm bands of LDCM.
- Compared in situ measurements to algorithm retrieved data to find RMSE of concentrations.

	CHL	TSS	CDOM
LDCM	1.4 2.1%	2.4 10.0%	2.7 19.3%
ETM+	1.1 1.6%	4.7 19.6%	2.1 15.0%

RMS of Residual Errors

	CHL(μg/L)	SM(mg/L)	CDOM(1/m)
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RMS of Residual Errors… (As Percentages)

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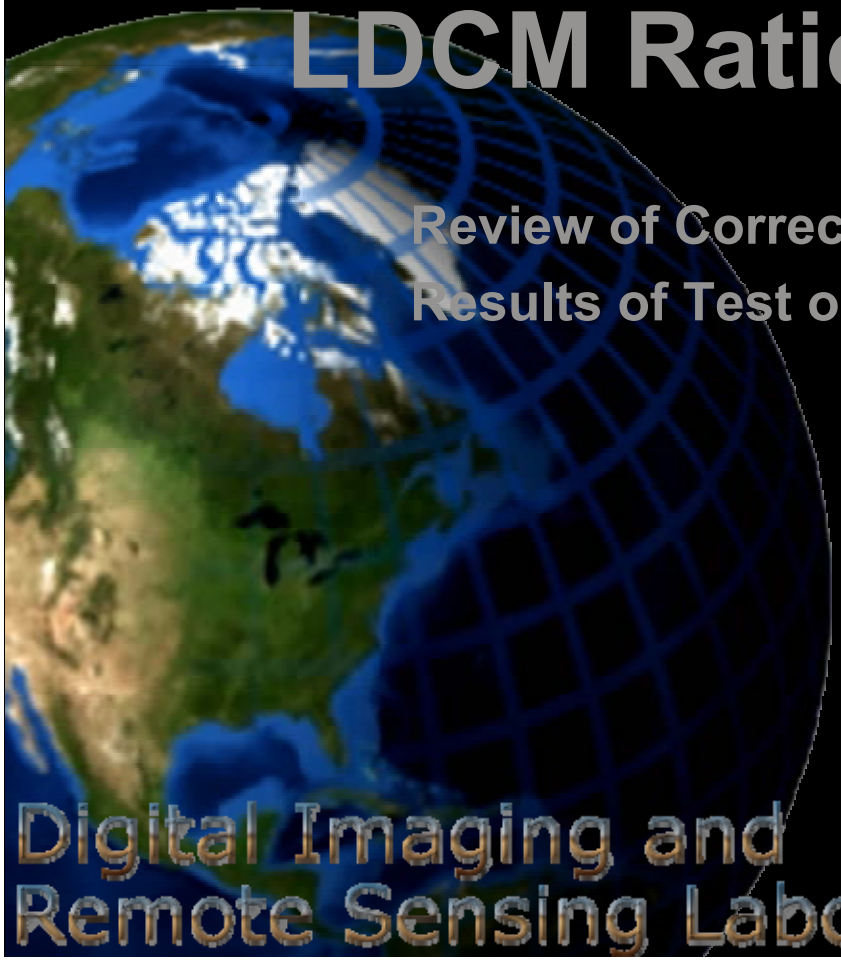
LDCM Ratios Update

Review of Correction Algorithm &
Results of Test on Simulated Data



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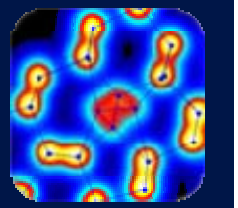
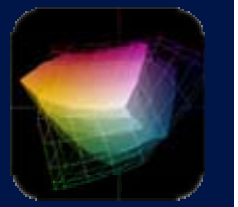
R·I·T





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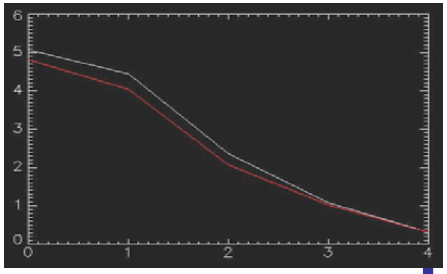
LDCM Approach

$$\rho_t(\lambda) = \rho_r(\lambda) + \rho_a(\lambda) + \rho_{ar}(\lambda) + \rho_g(\lambda) + t(\lambda)\rho_w(\lambda)$$

- **We remove glint to obtain…**

$$\rho_c = \rho_r(\lambda) + \rho_a(\lambda) + \rho_{ar}(\lambda) + t(\lambda)\rho_w(\lambda)$$



- **Because we are working over case 2 waters, we can't assume a zero water reflectance for NIR band.**
- **We do, however, have a spatially homogeneous body of water whose reflectance is fairly well known.**

LDCM Procedure

- Step 1: Remove glint from image
- Step 2: Create LUT of atmospheres that implements "spatially ambient reflectance"
- Step 3: Choose "ambient" ROI and find

$$\varepsilon = \frac{\rho_c^1}{\rho_c^5}$$

to determine appropriate atmosphere.

The Simulation

- **Used Hydrolight to create water samples that are representative of the Rochester embayment.**
  - **i.e. Lake Ontario (CHL=0.75, SM=0.50, CDOM=0.50) x 500**
    - **Cranberry Pond (5, 3, 5) x 500**
    - **Longpond (63, 22, 6) x 500**
    - **Genesee Plume (5, 8, 3) x 500**
    - **Braddocks Bay (6, 10, 9) x 500**
- **Propagated water-leaving signals to TOA using an arbitrary atmosphere…Marine aerosol, 30km visibility, standard water vapor, etc.**
- **Introduced noise and quantization to the 2500 sensor-reaching signals based on LDCM specifications.**
- **Attempted to recover constituent concentrations based on "imaged" water pixels using LDCM ratio technique and LUT inversion method.**

Results

	CHL(μg/L)		SM(mg/L)		CDOM(1/m)	
Perfect Atmospheric Compensation	2.2	3.2%	0.6	2.5%	0.5	3.6%
LDCM Ratio Technique use to compensate for atmosphere.	5.54	8.1%	2.56	10.4%	1.95	13.9%

- **For real data**
  - **Adjacency effects**
  - **Rms. vs. ratio comparison**