



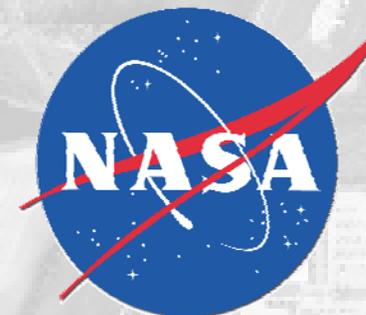
# Historic Thermal Calibration of LANDSAT 5 TM through an Improved Physics Based Approach

**M.S. Thesis Defense**

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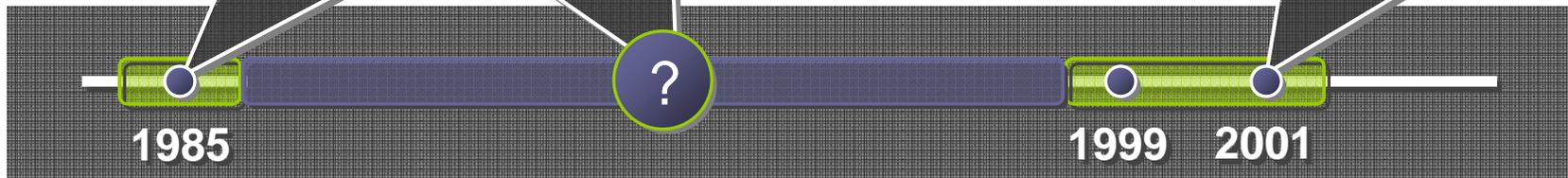
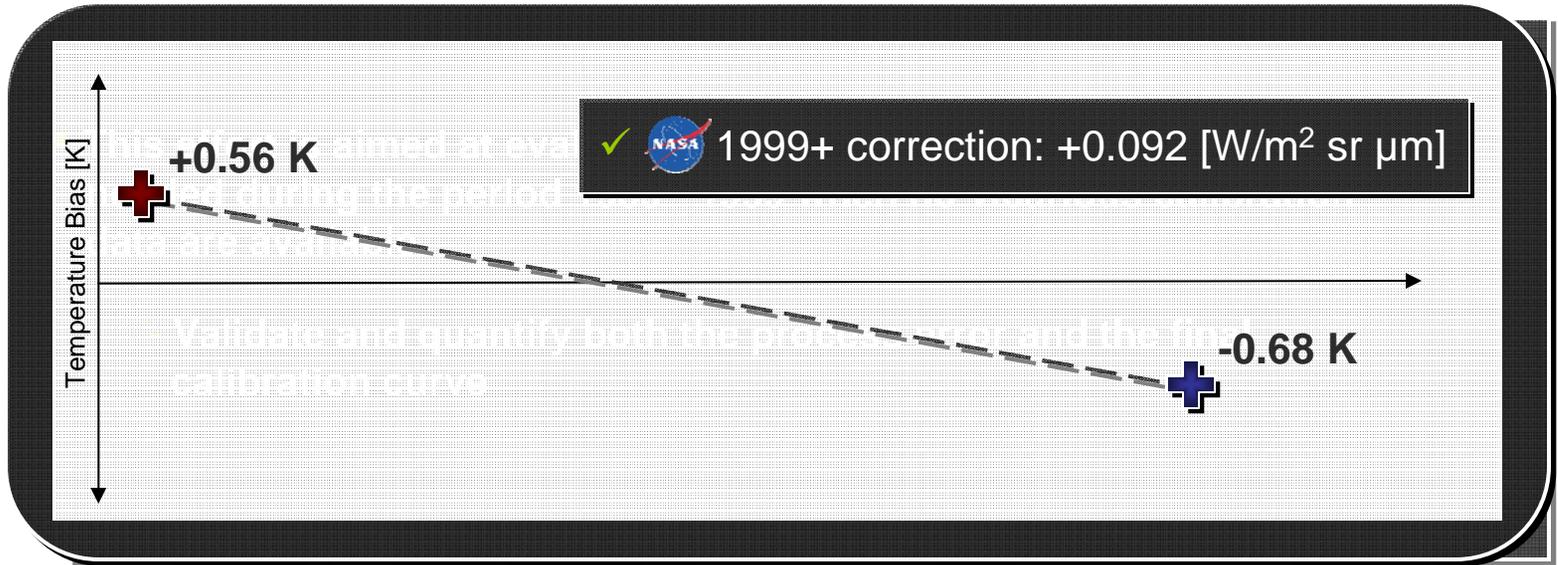




# Calibration History

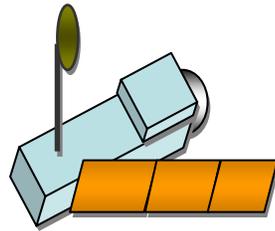


## Landsat 5 TM Band 6 Calibration History

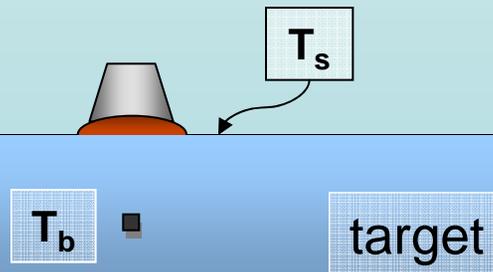




# Process Overview

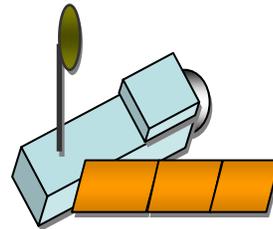


- 4 **Compare in-situ derived effective radiance to Image derived effective radiance**  
(reveal potential bias of the sensor)
- 3 **Extract image ROI about buoy locale (3x3)**  
(convert DC to radiance)
- 2 **Propagate Ground Truth to space**  
 $T_s \rightarrow$  sfc radiance  $\rightarrow$  atmosphere  
(predicted)
- 1 **convert  $T_b \rightarrow T_s$  for correlation with remotely sensed radiometric temperature**  
(ground truth)





## Physical Modeling: 2 Main Thrusts



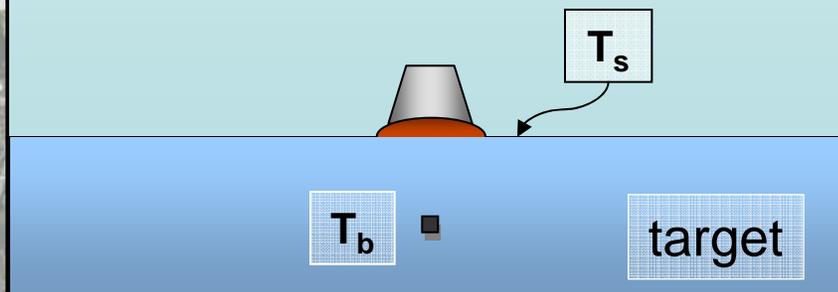
2

**Propagate Ground Truth to space**

$T_s \rightarrow$  sfc radiance  $\rightarrow$  atmosphere  
(predicted)

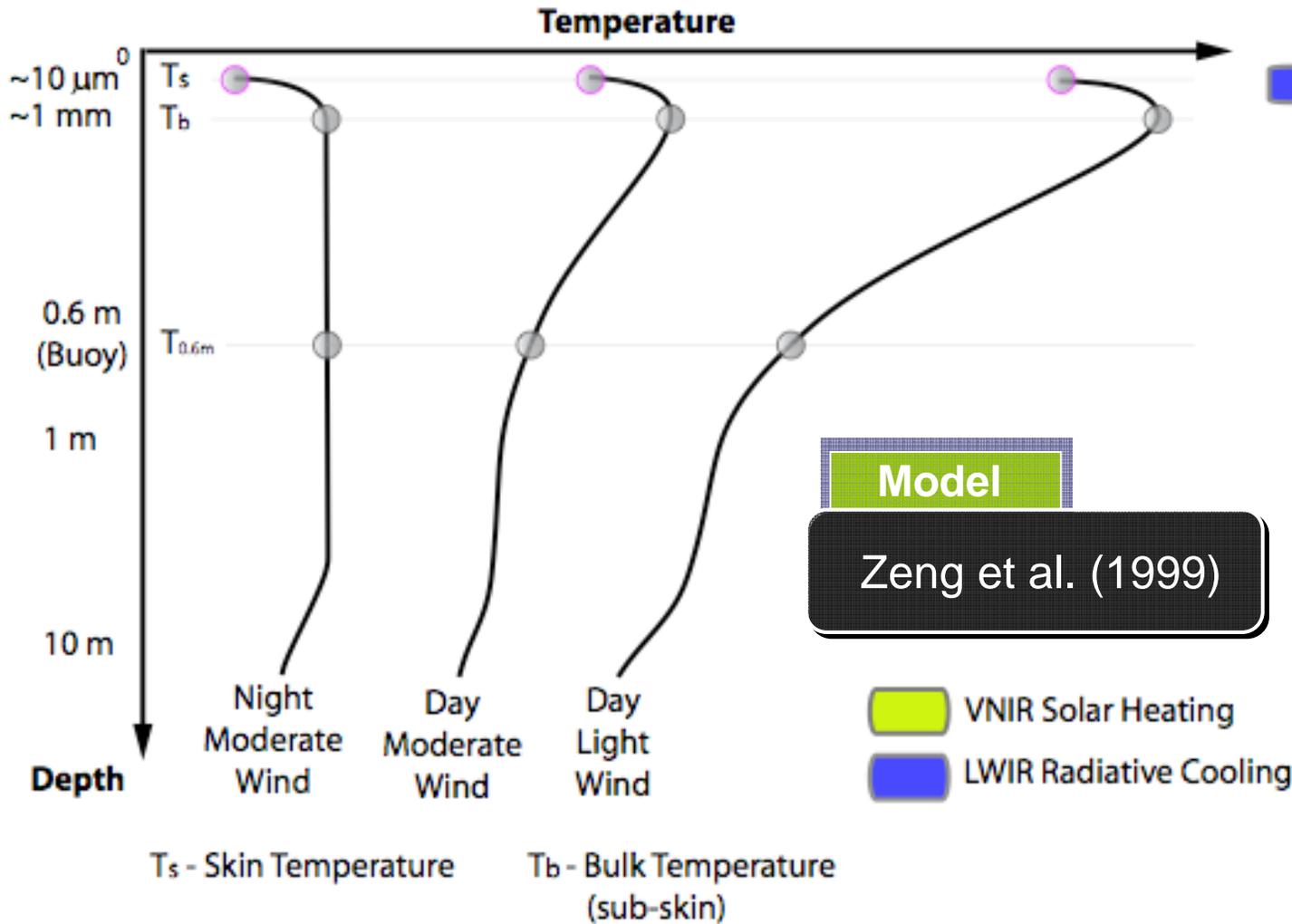
1

**convert  $T_b \rightarrow T_s$  for correlation**  
with remotely sensed radiometric  
temperature  
(ground truth)



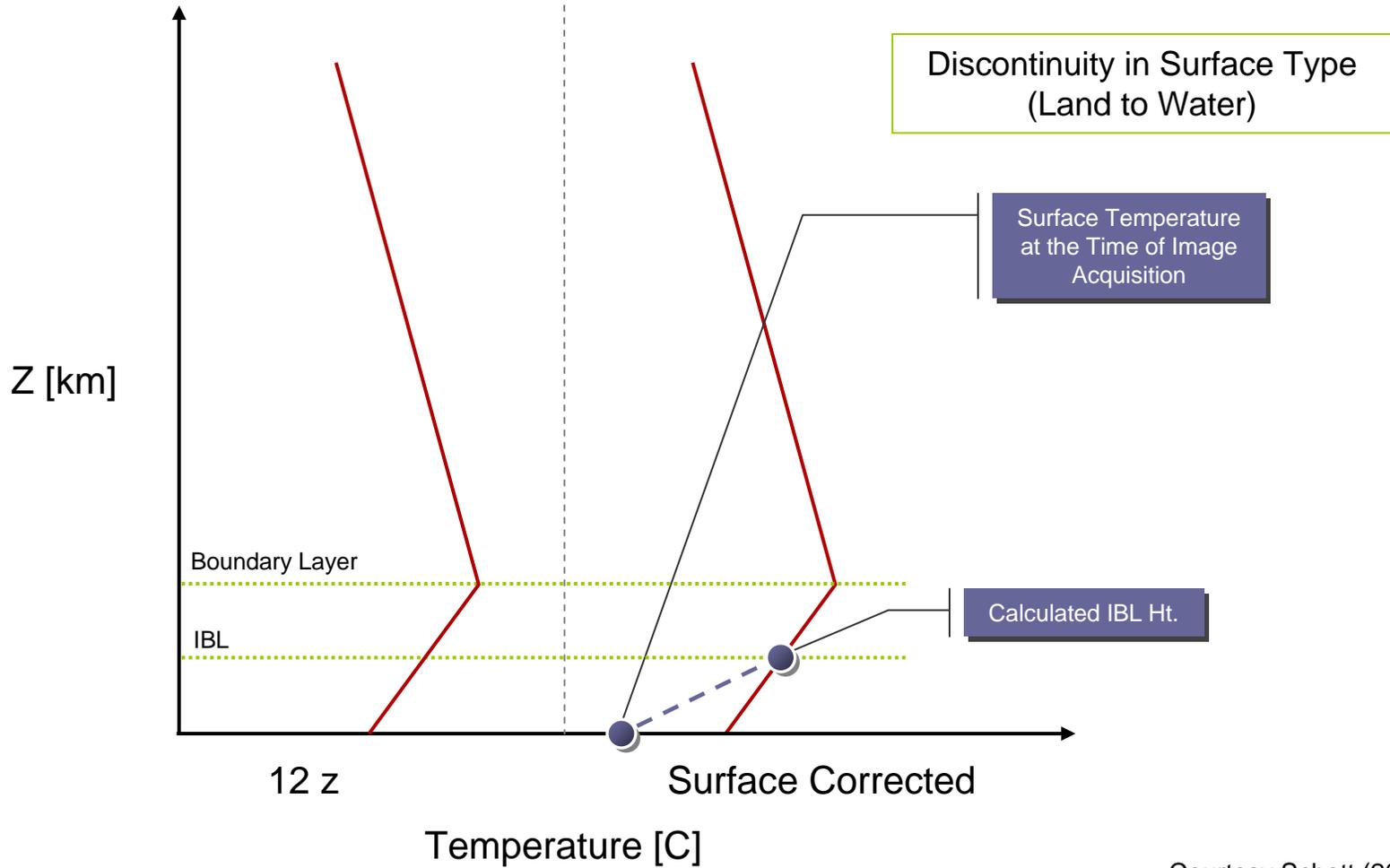
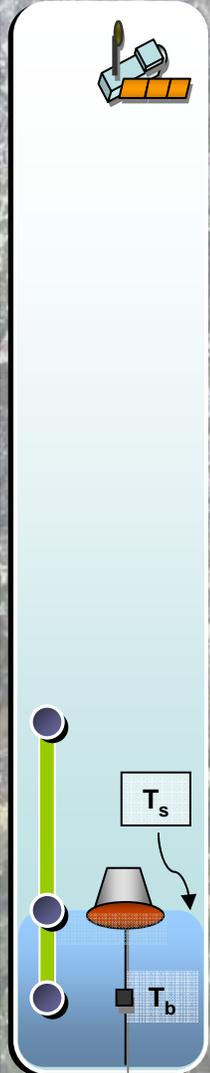


# Phenomenology





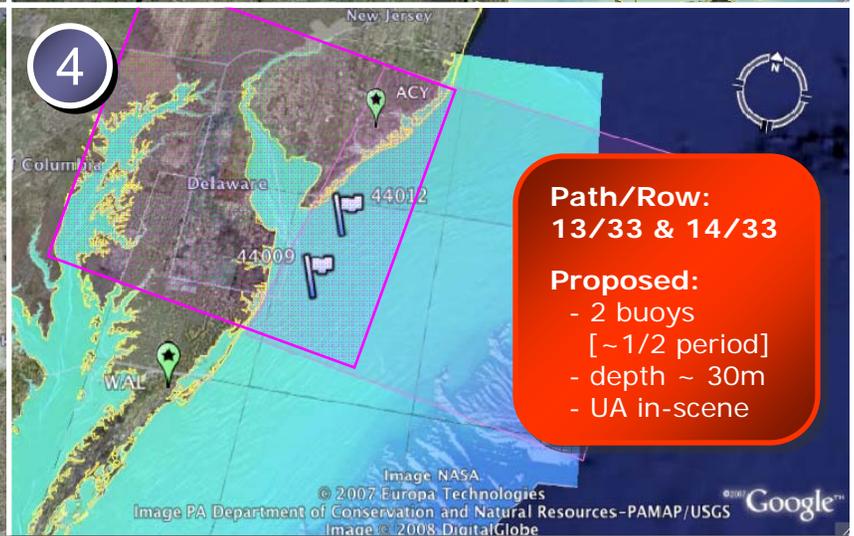
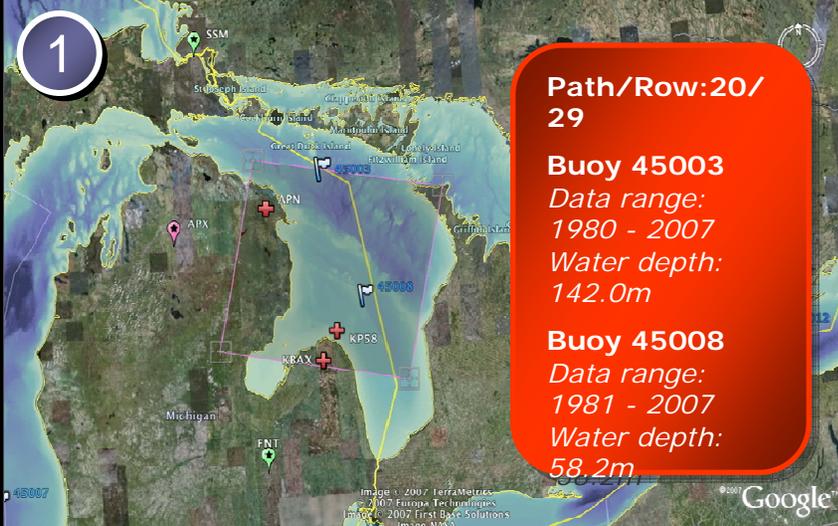
# IBL Surface Correction



Courtesy Schott (2007)



# Calibration Sites



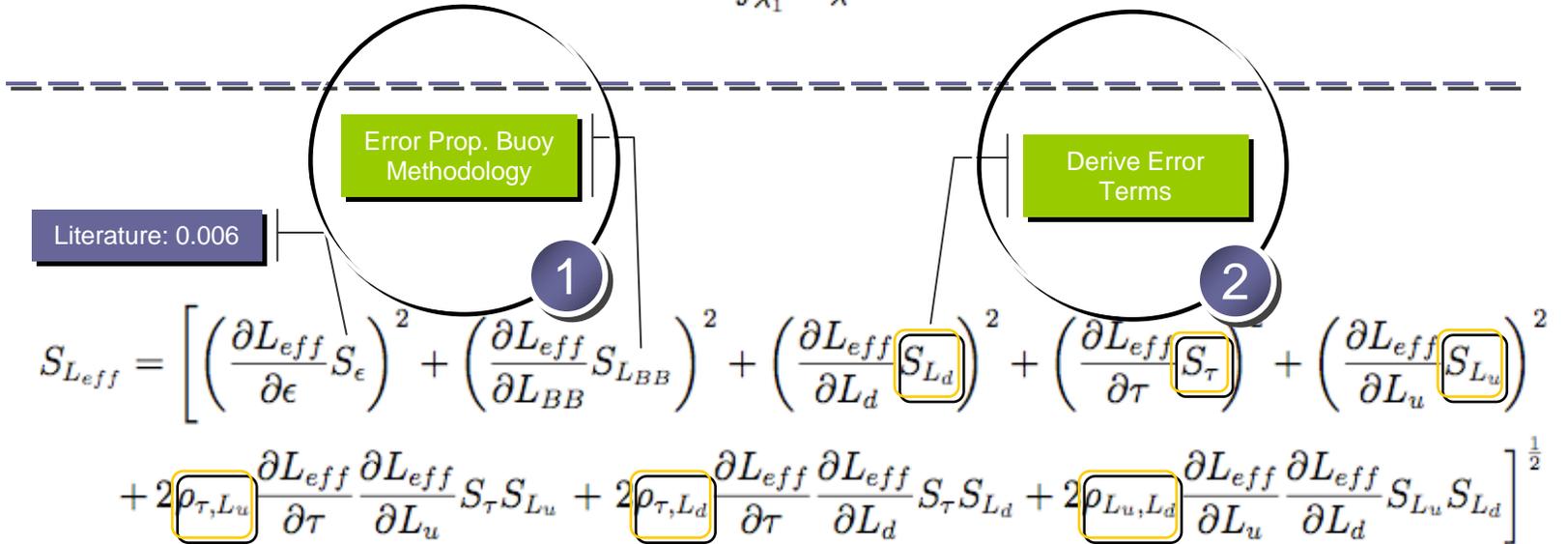


# Determination of Process Error



**Gov. Eq. expressed using Beers Method of Error Propagation:**

**Gov. Eq:** 
$$L_{eff} = \frac{\int_{\lambda_1}^{\lambda_2} ((\epsilon L_{BB} + (1 - \epsilon)L_d)\tau + L_u)R'_\lambda d\lambda}{\int_{\lambda_1}^{\lambda_2} R'_\lambda d\lambda}$$



Assumptions: error in responsivity and error in computation of the Planck Eq. is negligible



## Total Process Error



- ✓ Due to the (negative signed) correlation term  $\rho_{\tau, Lu}$
- ✓ Expected error of  $\pm 0.454$  K
- ✓ **Most dominant:** target temperature term (LBB), where the emissivity term was found to most dominant at high target temperatures (i.e. 300 K) except for warm moist atmospheres
- ✓ **Most sensitive:** the emissivity term which was eventually overtaken by the transmission term  $\tau$  in the presence of warm and highly moisture rich atmospheric profiles



# Landsat 7 Comparison Study



## Validate the Proposed Methodology:

- Landsat 7: ETM+
  - » thermal band (Band 6)
  - » monitored closely since launch (April 15, 1999) RIT and JPL
- Use the proposed methodology to build a calibration curve using Landsat 7 data
- Results are compared both RIT and JPL vicarious calibration data

QuickTime™ and a  
TIFF (Uncompressed) decompressor  
are needed to see this picture.



# Landsat 7 Comparison Study



ETM: Thermal Calibration Data: RIT

## Traditional Methods of Ground Truth Collection:

- $y = 0.9525x + 0.3513$
- ✓ regression lines found to be not statistically different at the 99% C.I. (F-test testing: slope and intercept)
  - ✓ temperature bias from each method was found to be not statistically different at the 99% C.I. (2 sampled t-test)
  - ✓ establishes a high level of confidence in the method

In-situ derived top-of-atmosphere radiance [ $W/m^2/\mu m$ ]

RIT: Landsat 5 Thermal Calibration

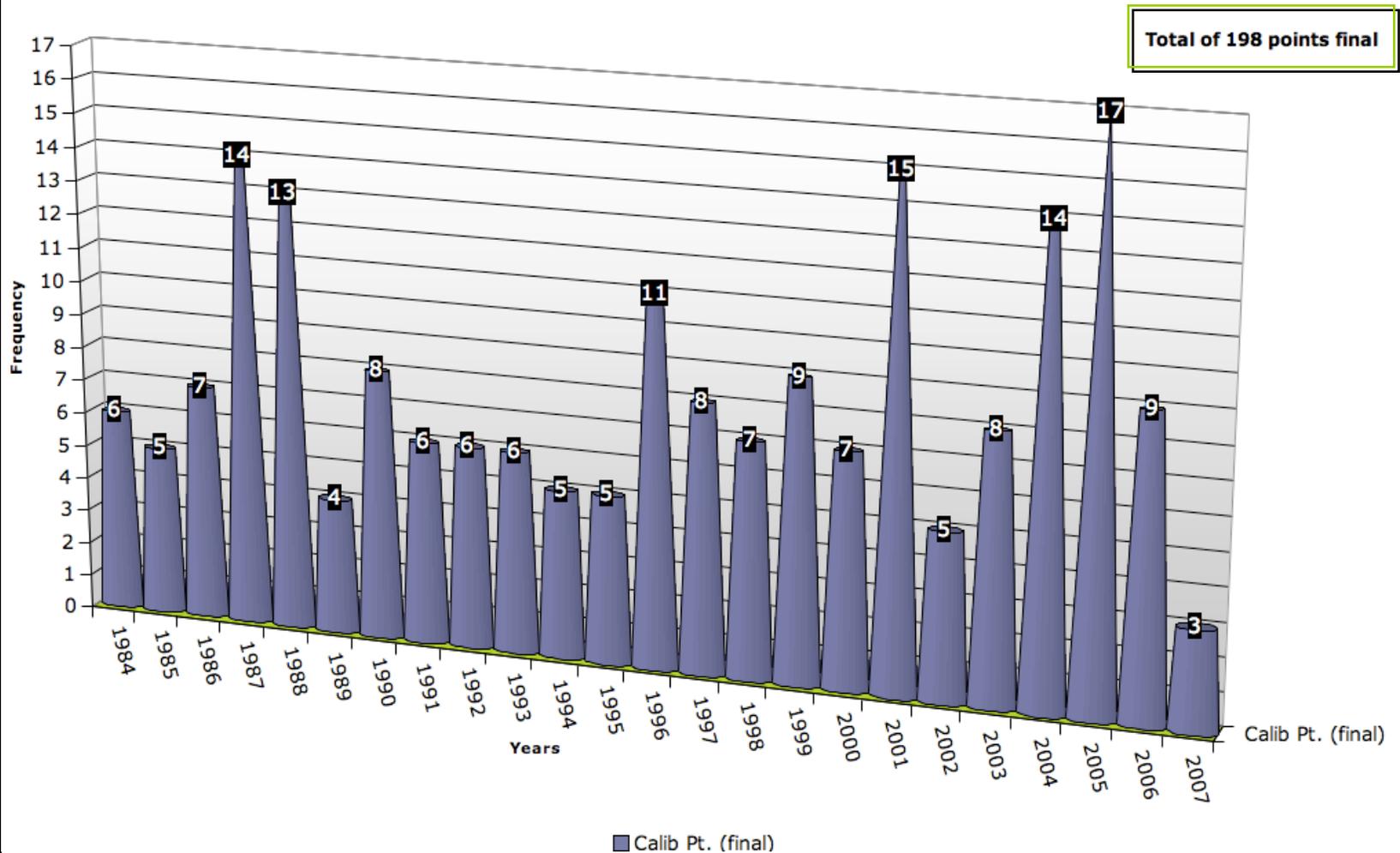
RIT: Landsat 5 Thermal Calibration



# Data Coverage



Data Coverage

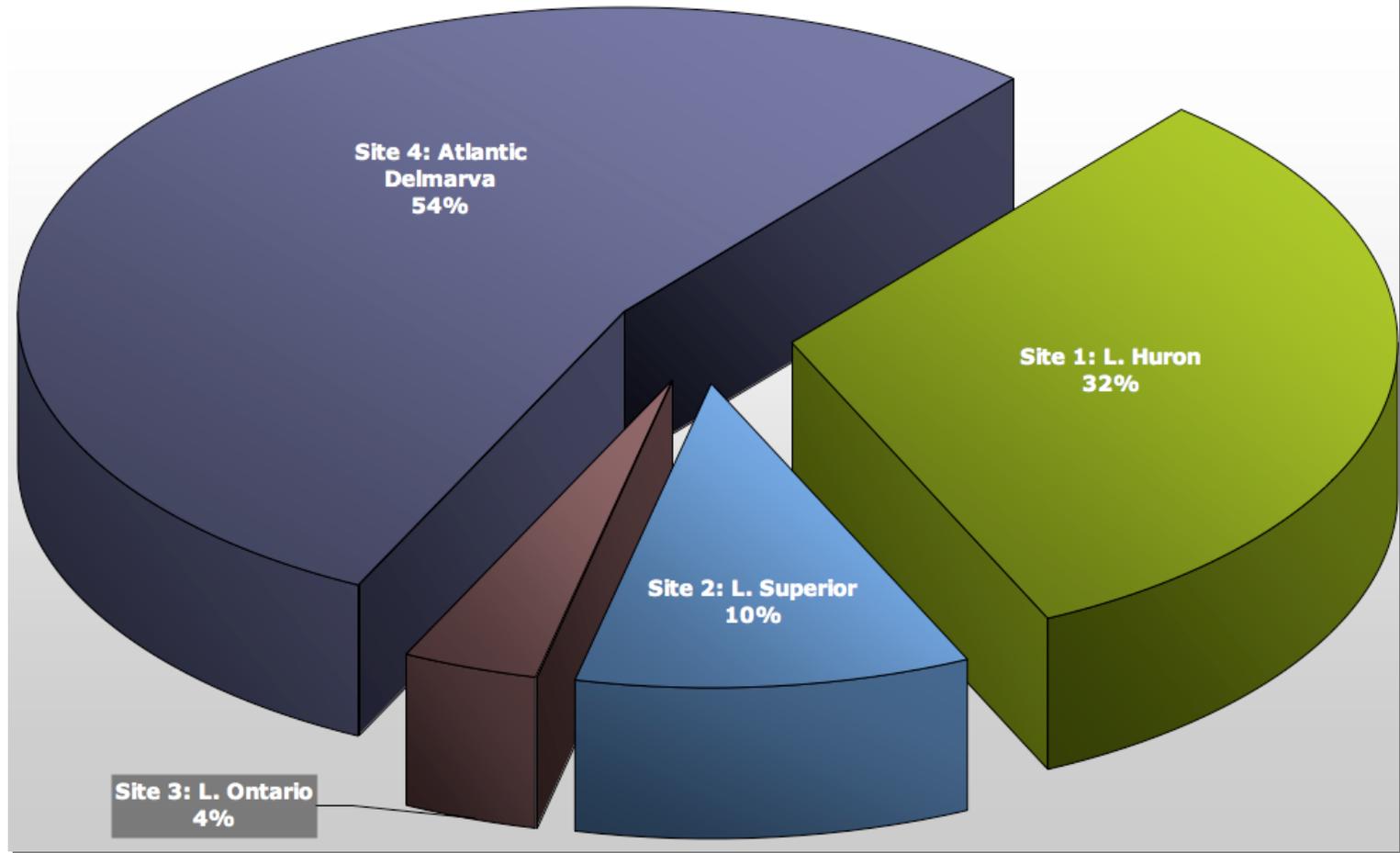




# Site Contribution



Site Contribution





# Uncorrected Radiance Data



RIT: Landsat 5 Thermal Calibration

## Analysis and Summary of the Uncorrected Data set:

$$y = 0.8929x + 0.7608$$

$$R^2 = 0.9874$$

- ✓ An event occurring around 1999 caused a significant change in sensor bias

$$y = 0.9121x + 0.4692$$

$$R^2 = 0.9928$$

- ✓ Data prior to and post 1999 have statistically different temperature bias
- ✓ Time dependent correction is necessary
- ✓ The instrument has fluctuated only slightly over the lifetime of the instrument: RMSE = 1.064 K (99% C.I.)

- ✓ Temperature bias was found statistically different 99% C.I.

In situ derived top-of-atmosphere radiance (W/m<sup>2</sup>/sr/m)

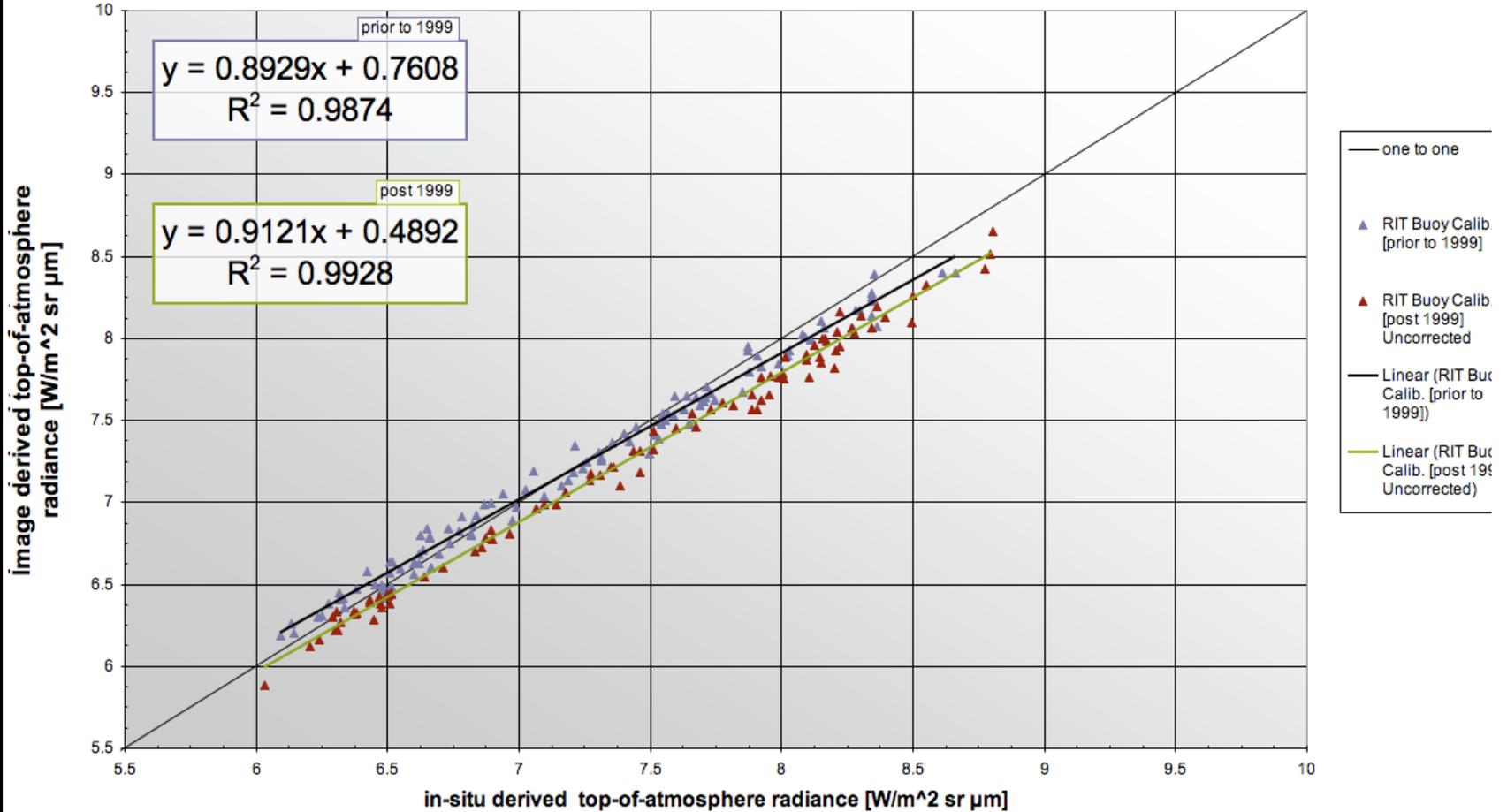
RIT: Landsat 5 Thermal Calibration



# Recommended Correction



TM Thermal Calibration Data: RIT  
[filtered & 1999 plus uncorrected]





# Recommended Correction



## Analysis and Summary of the Uncorrected Data set:

- ✓ The correction successfully removed the gain issue and bias over time
- ✓ Linear (Dual: Slope & Intercept) Correction: RMSE of 0.488 K
- ✓ Reduction in RMSE compared to the filtered & uncorrected data of 0.576 K
- ✓ The Linear (Dual: Slope & Intercept) Correction demonstrates a bias over time -0.1 K (warm bias to a cold bias) over the lifetime of the instrument
- ✓ Bias over time was found to be not statistically different from zero