GSICS
Requirements for SST

Andy Harris
Eileen Maturi
Jon Mittaz
Prabhat Koner

Geo-SST Processing

- Uses CRTM forward-modeled BTs
  - Bayesian cloud detection
  - Developing new “double-difference” tests
  - Deterministic physical retrieval
- “Deterministic”
  - Regularization of gain matrix is dynamically data-driven, as opposed to specified via *a priori* covariances
    - Koner, P.K., A.R. Harris & E. Maturi, ‘A physical deterministic inverse method for operational satellite remote sensing: an application for sea surface temperature retrievals’, IEEE-TGRS, **53**, 5872-5888, 2015

History of Inverse Model

- **Forward model:** $\mathbf{Y} = \mathbf{K}\mathbf{X}$
- **Simple Inverse:** $\mathbf{X} = \mathbf{K}^{-1}\mathbf{Y}$ **(measurement error)**

- **Legendre (1805) Least Squares:**

$$\mathbf{X} = \mathbf{X}_{ig} + (\mathbf{K}^{T}\mathbf{K})^{-1}\mathbf{K}^{T}(\mathbf{Y}_{\delta} - \mathbf{Y}_{ig})$$

- **MTLS:** $\mathbf{X} = \mathbf{X}_{ig} + (\mathbf{K}^{T}\mathbf{K} + \lambda\mathbf{R})^{-1}\mathbf{K}^{T}(\mathbf{Y}_{\delta} - \mathbf{Y}_{ig})$

- **OEM:** $\mathbf{X} = \mathbf{X}_{a} + (\mathbf{K}^{T}\mathbf{S}_{e}^{-1}\mathbf{K} + \mathbf{S}_{a}^{-1})^{-1}\mathbf{K}^{T}\mathbf{S}_{e}^{-1}(\mathbf{Y}_{\delta} - \mathbf{Y}_{a})$

Uncertainty Estimation

Physical retrieval

Normal LSQ Eqn: $\Delta x = (K^T K)^{-1} K^T \Delta y \quad [= G\Delta y]$

MTLS modifies gain: $G' = (K^T K + \lambda I)^{-1} K^T$

Regularization strength: $\lambda = (2 \log(\kappa) / ||\Delta y||) \sigma^2_{end}$

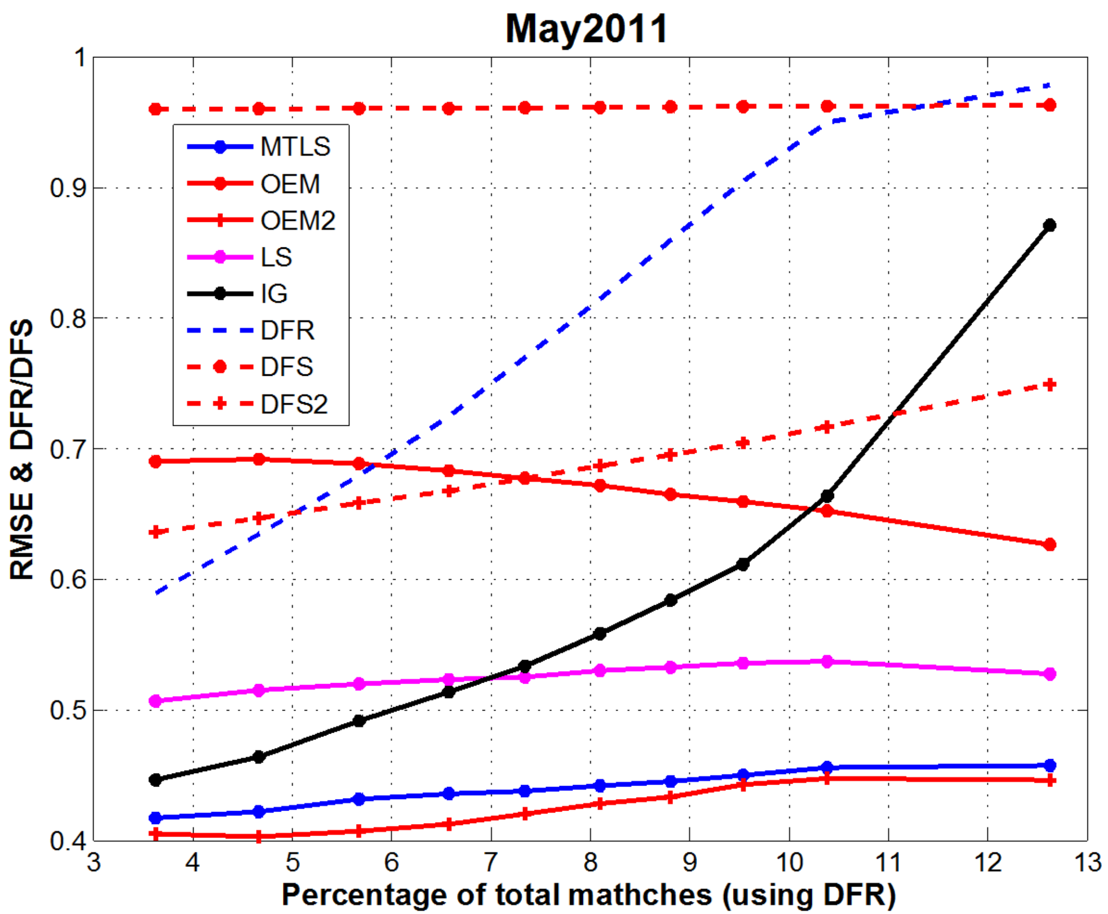
(σ_{end} = lowest singular value of $[K\ \Delta y]$)

Total Error

$$||e|| = ||(MRM - I)\Delta x|| + ||G'|| \langle ||(\Delta y - K\Delta x)|| \rangle$$

N.B. **Includes TCWV as well as SST**

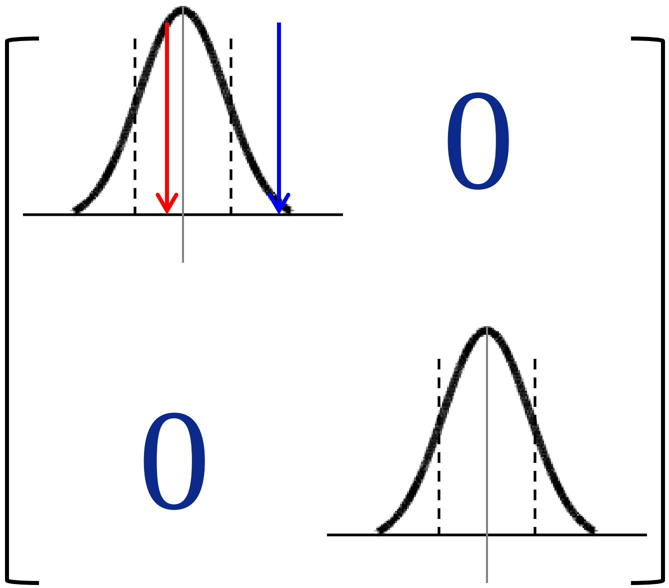
DFS/DFR and Retrieval error



- Retrieval error of OEM higher than LS
- More than 75% OEM retrievals are degraded w.r.t. *a priori* error
- DFR of MTLS is high when *a priori* error is high

“Optimized” OE

- $[S_e]$, S_a =

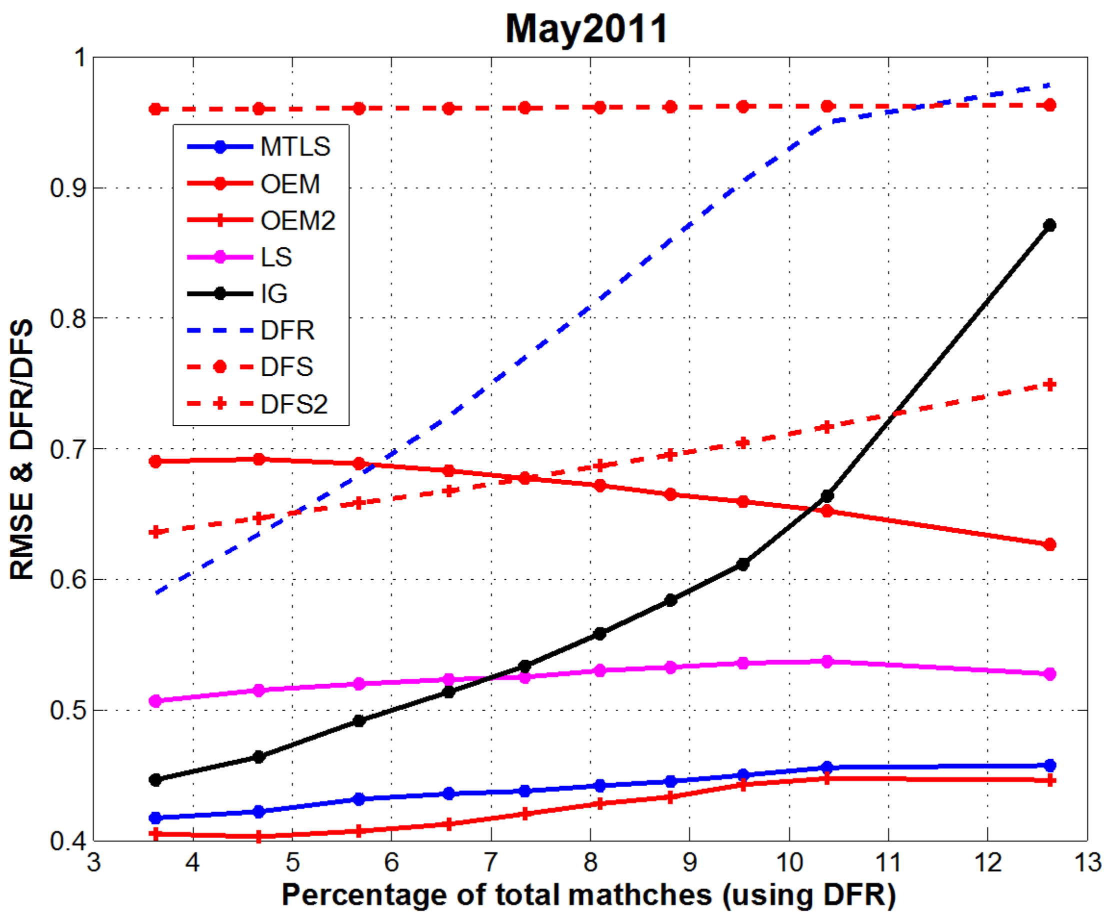


σ^2 is an overestimate…

…or an underestimate

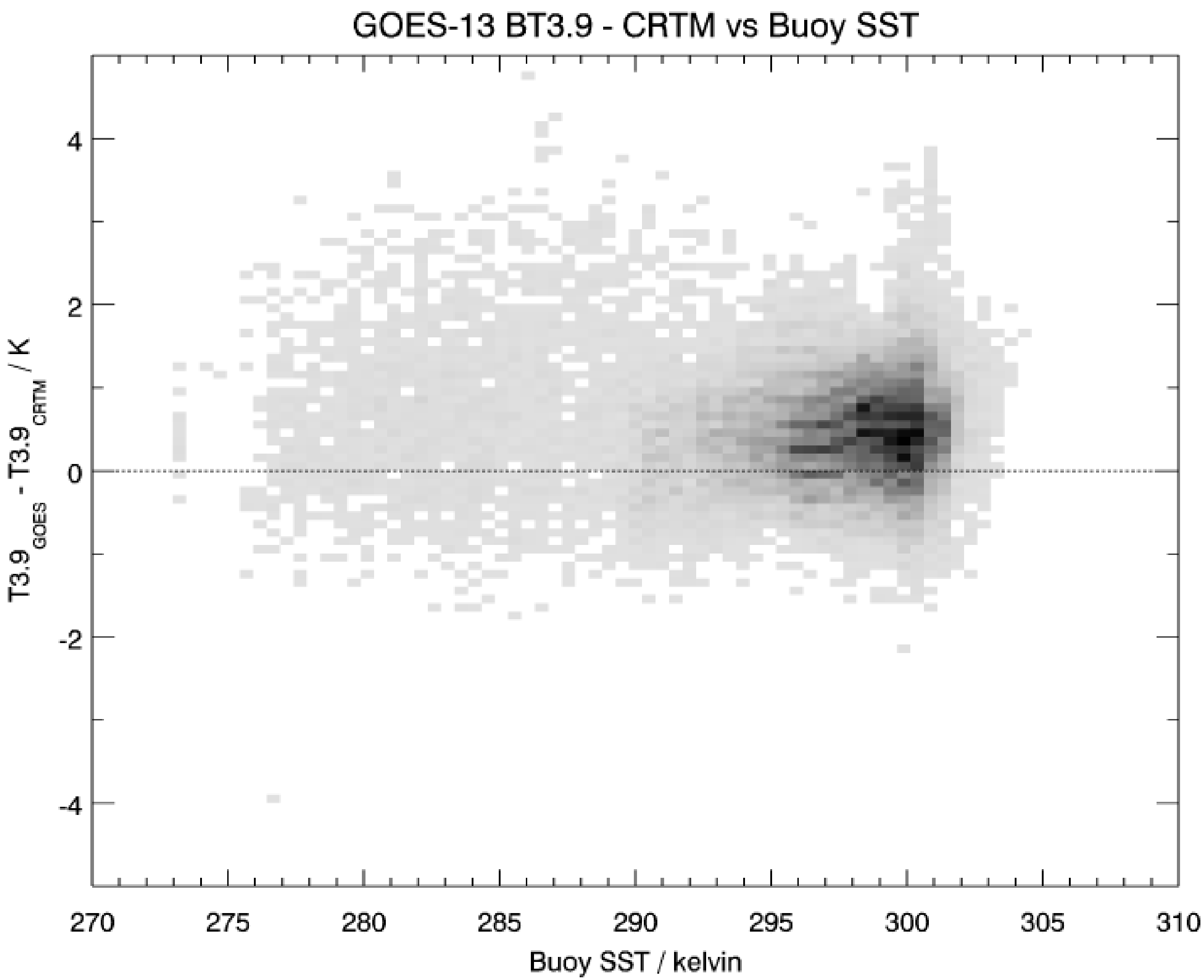
- **Perform experiment – insert “true” SST error into S_a^{-1}**
  – Can only be done when truth is known, *e.g.* with matchup data

DFS/DFR and Retrieval error



- Retrieval error of OEM higher than LS
- More than 75% OEM retrievals are degraded w.r.t. *a priori* error
- DFR of MTLS is high when *a priori* error is high
- The retrieval error of OEM is good when *a priori* SST is perfectly known, but DFS of OEM is much lower than for MTLS

Effect of GSICS Calibration on Satellite – CRTM BTs



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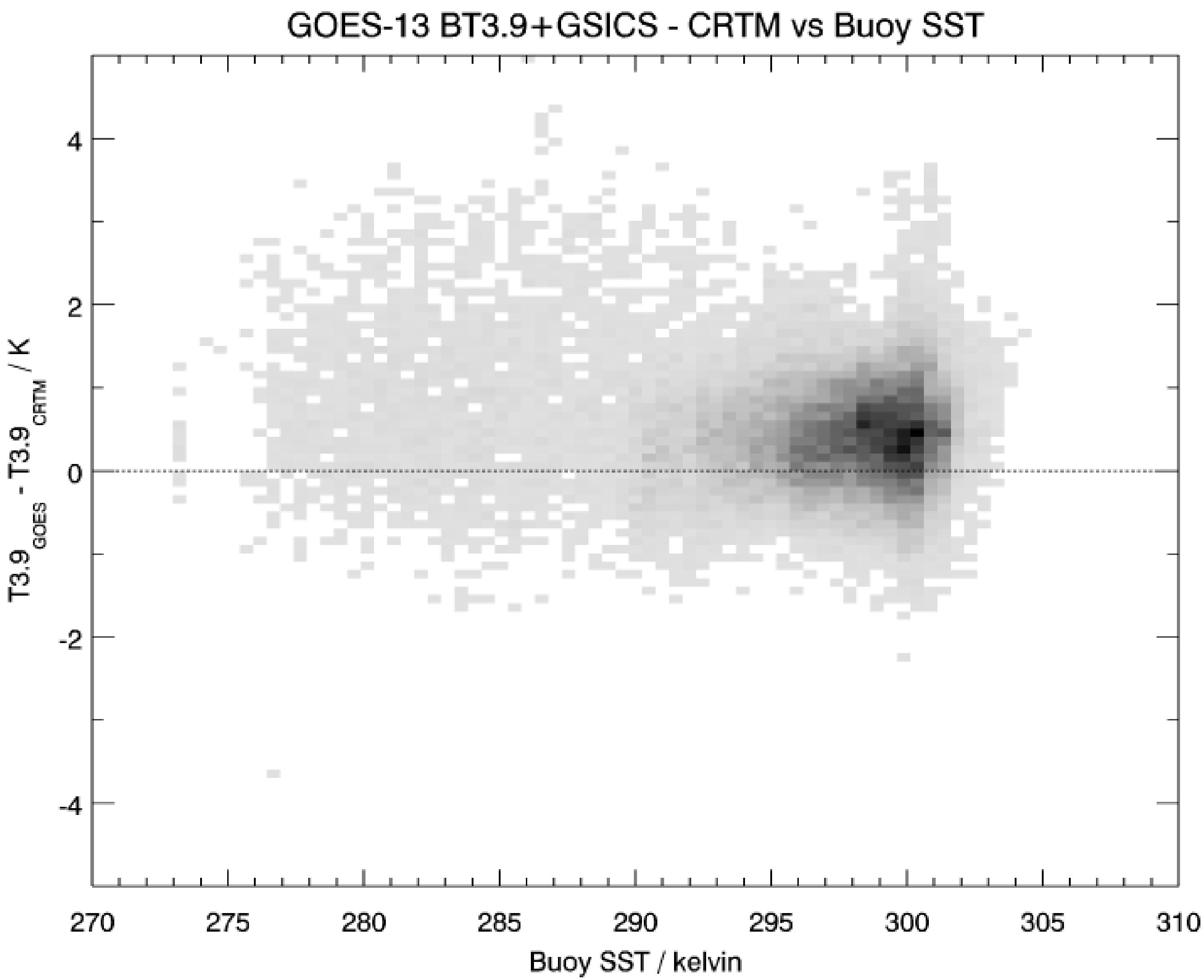

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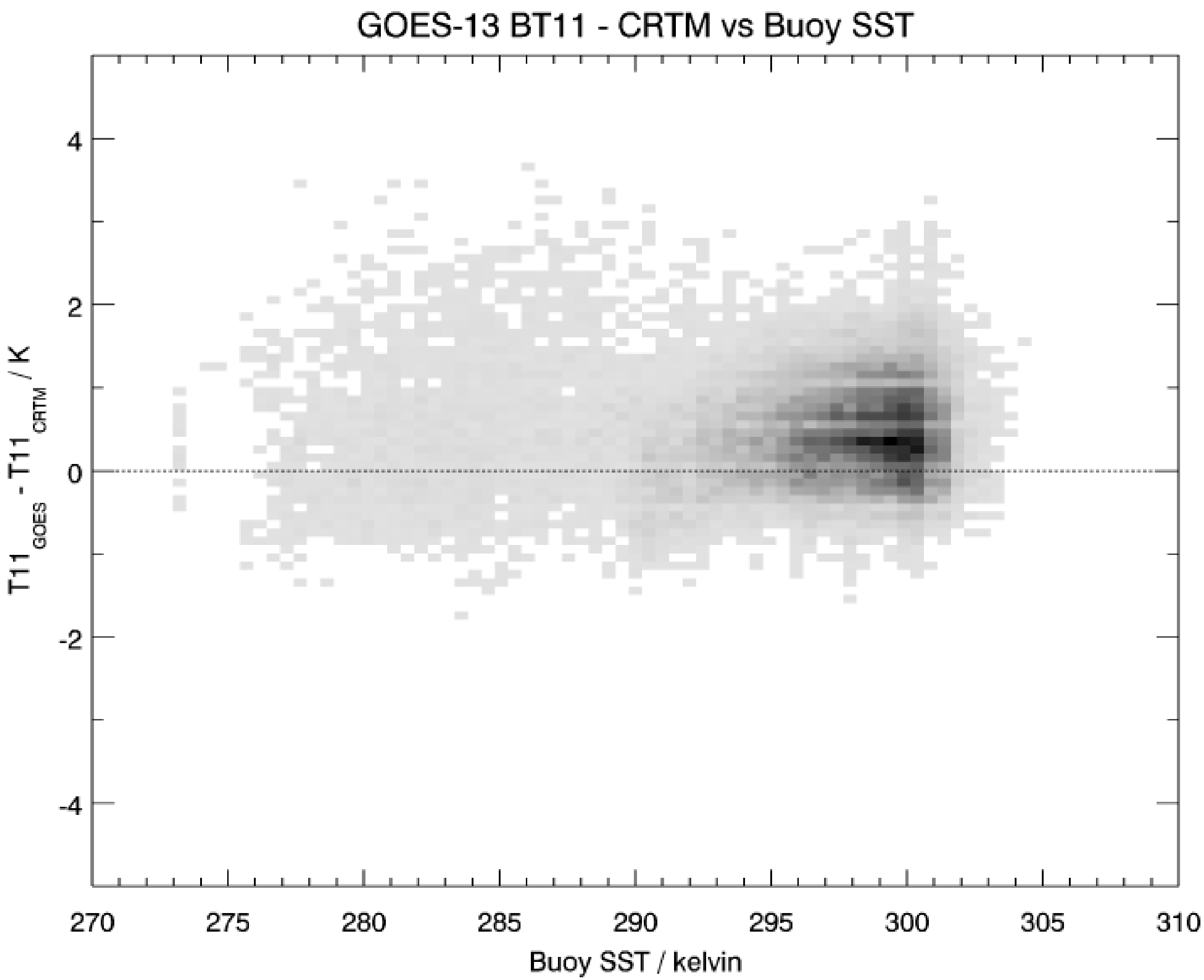

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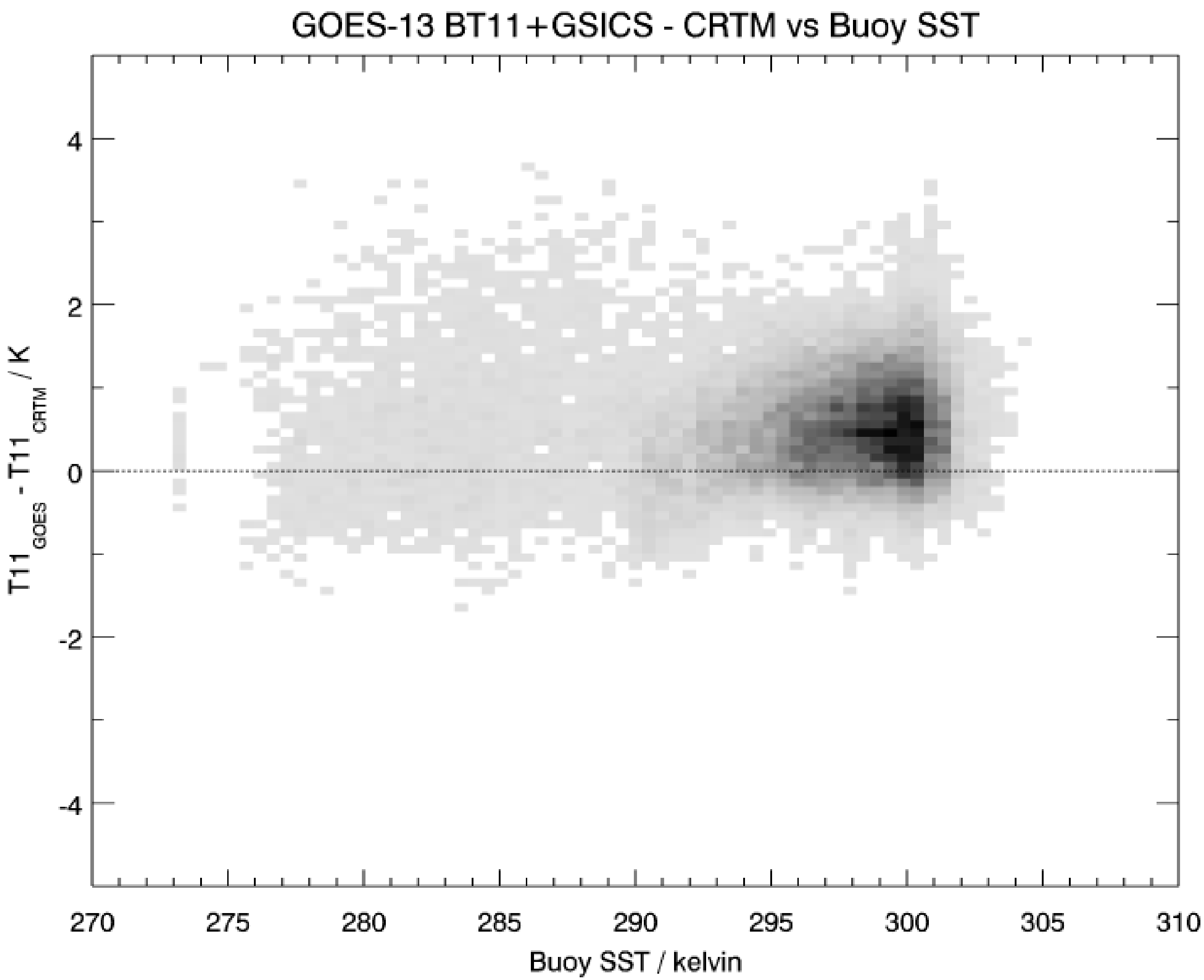

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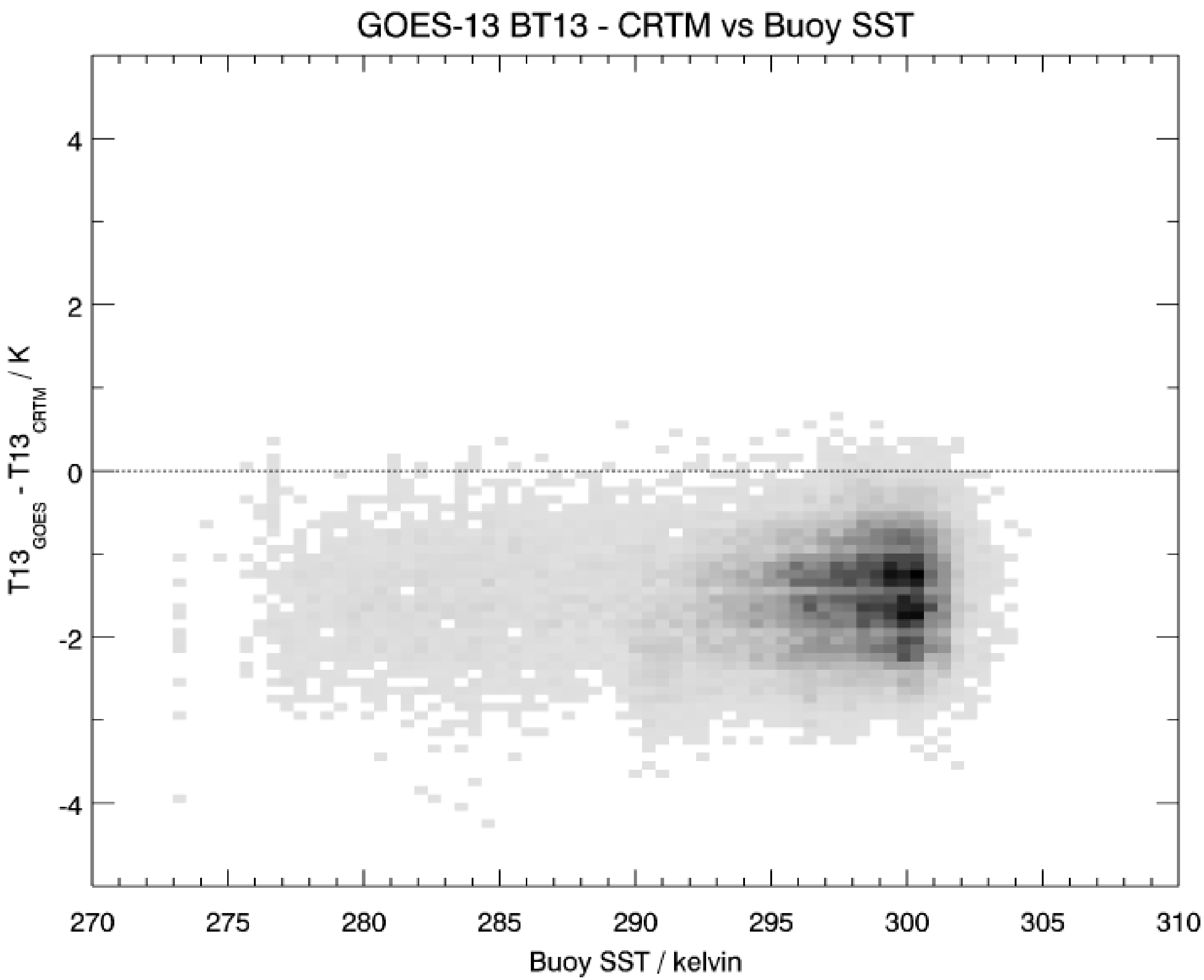

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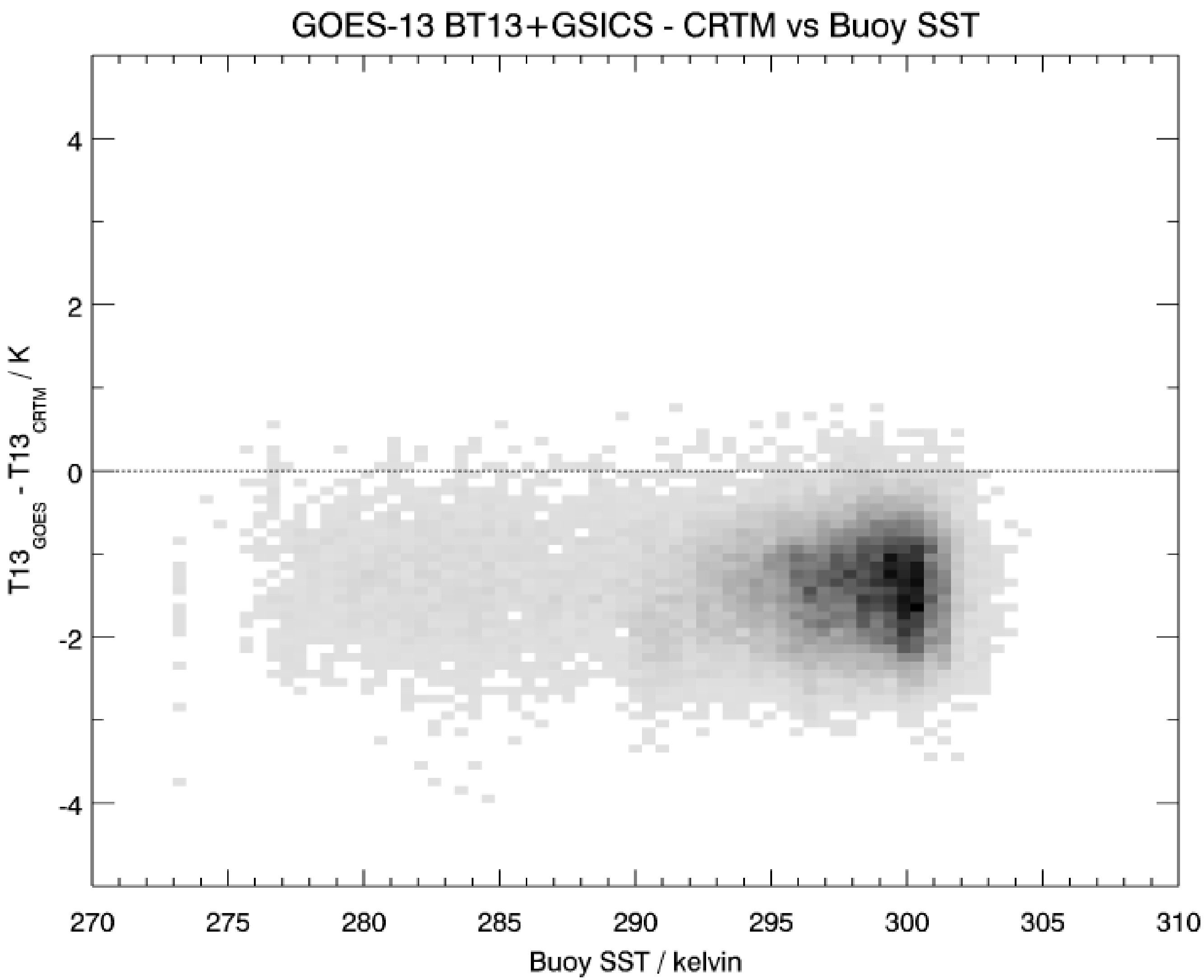

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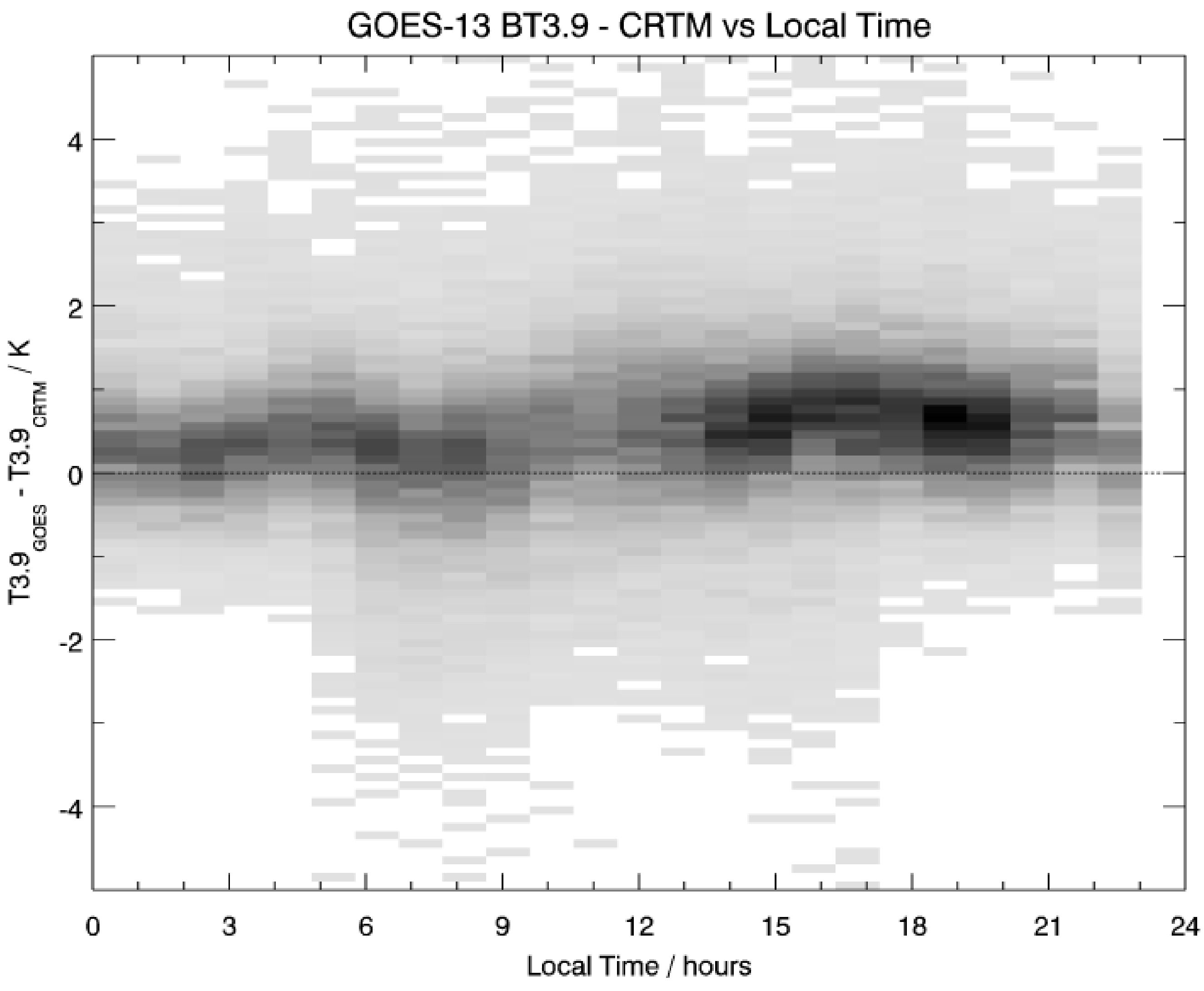

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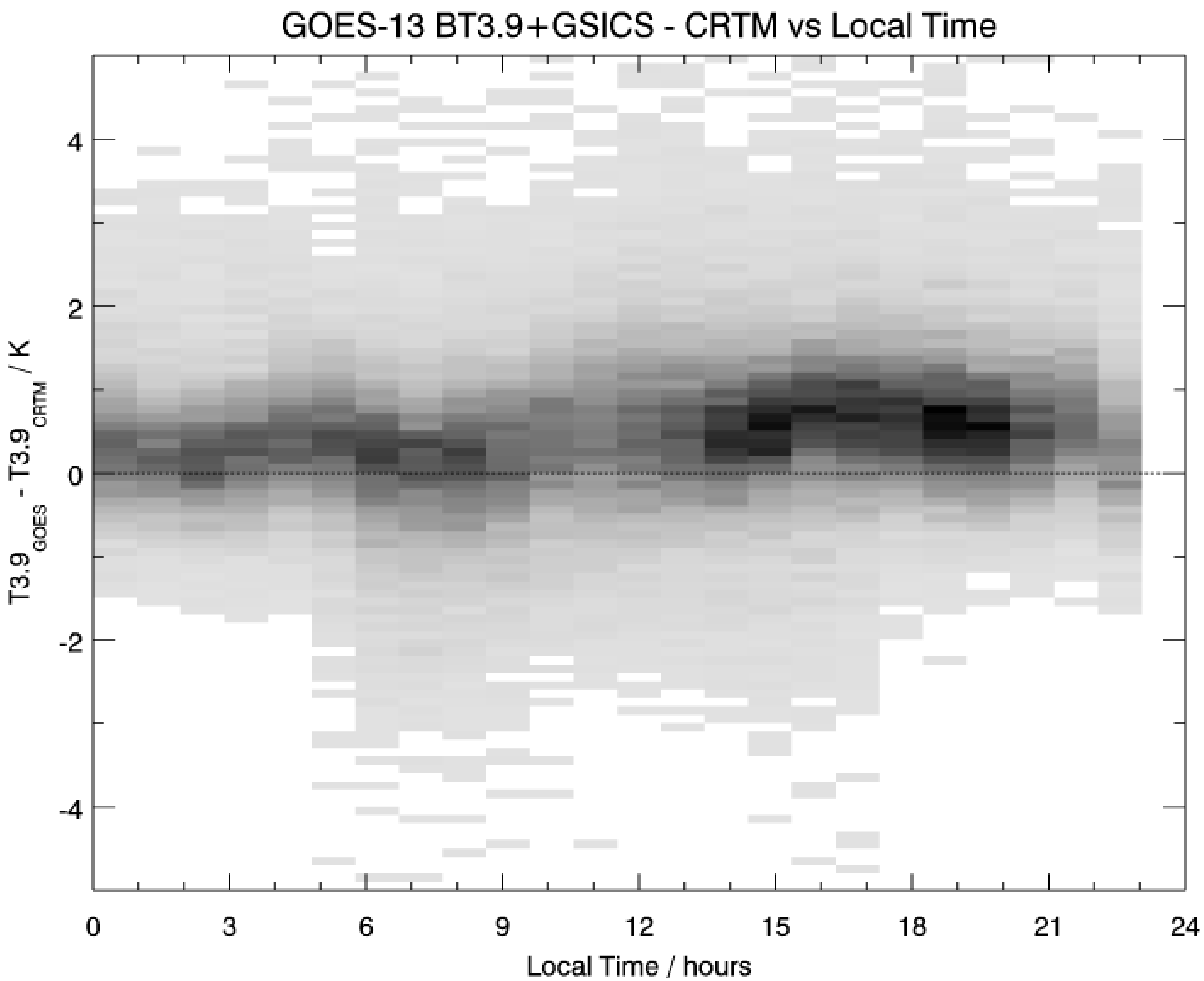
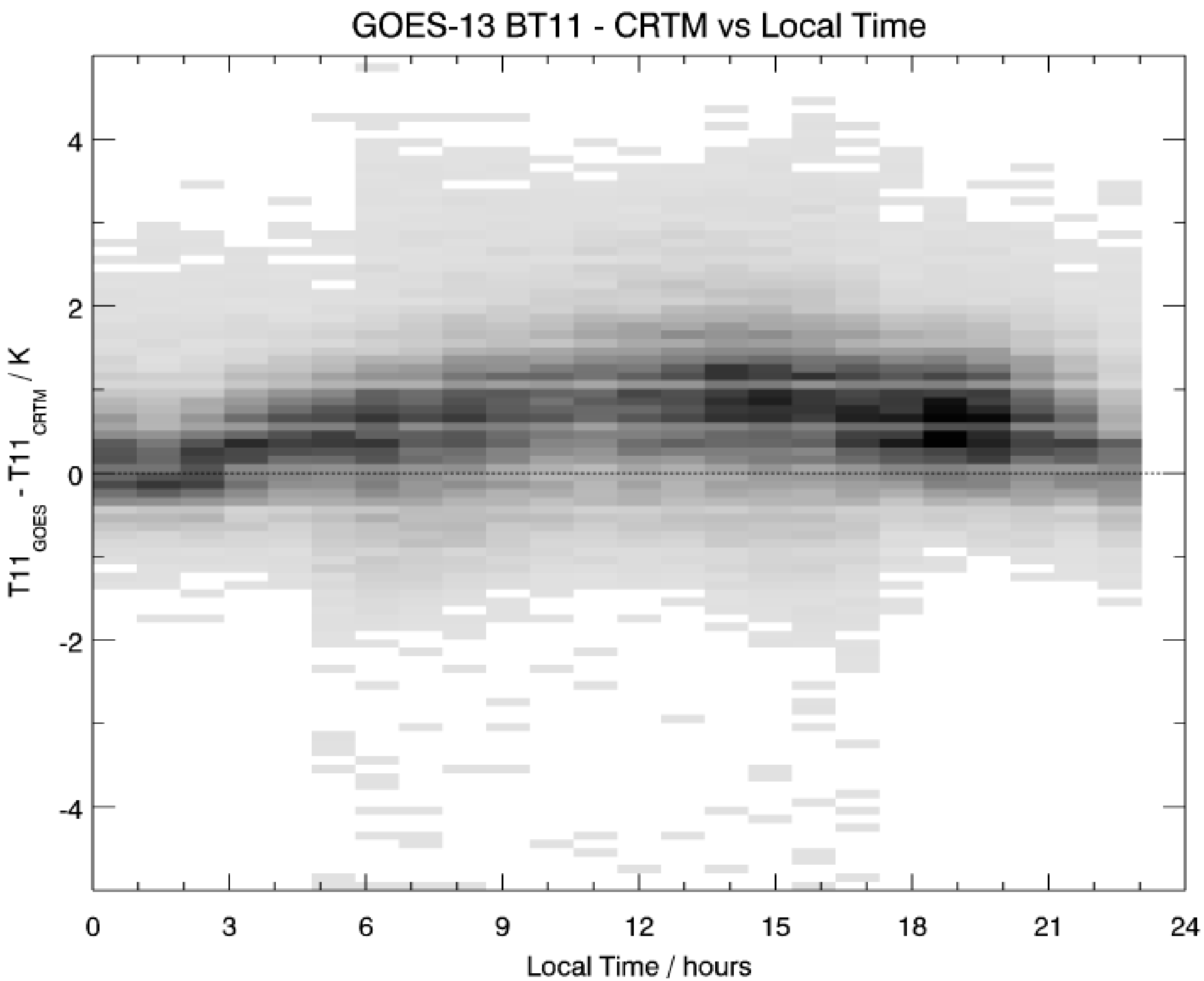


Effect of GSICS Calibration on Satellite – CRTM BTs



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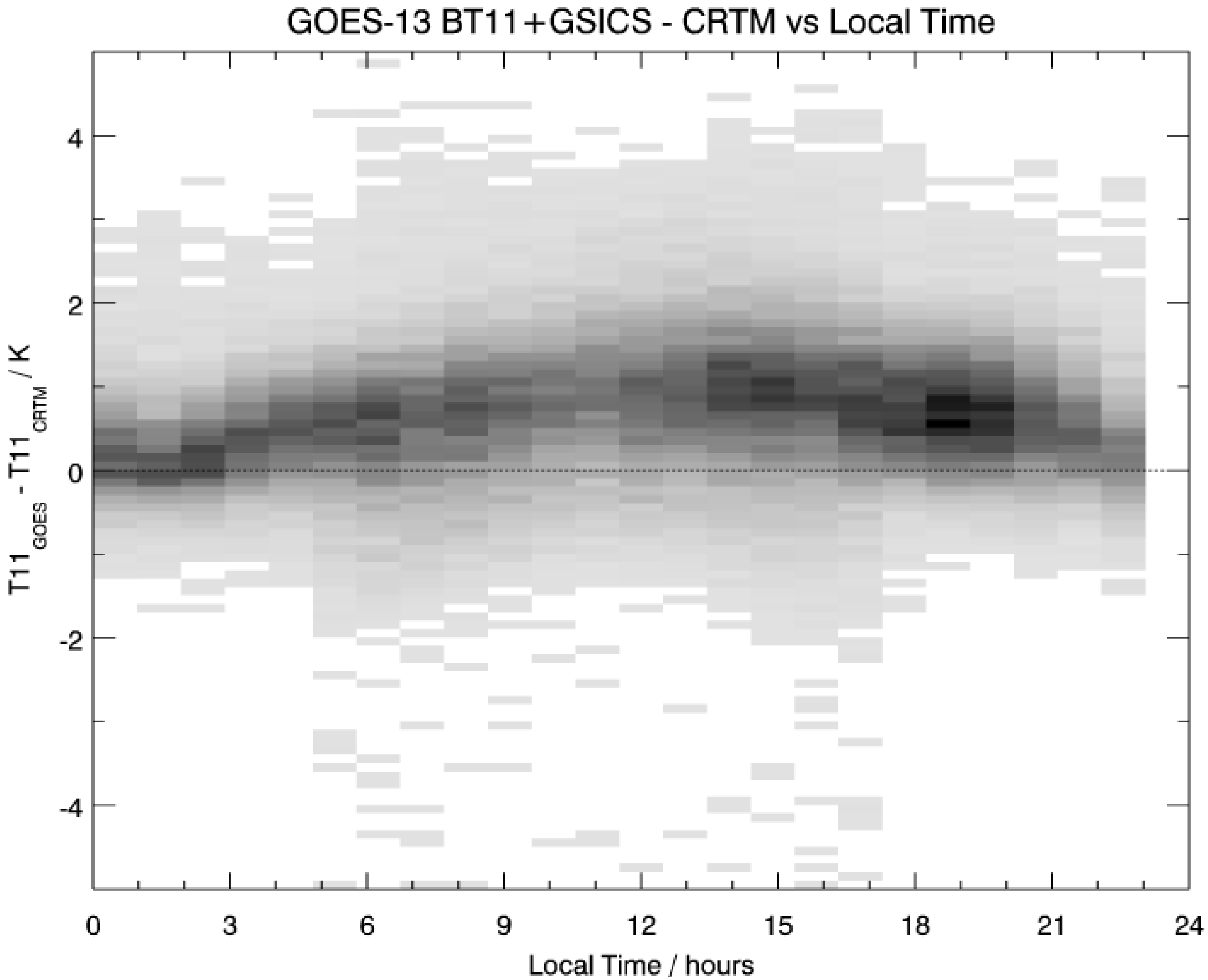

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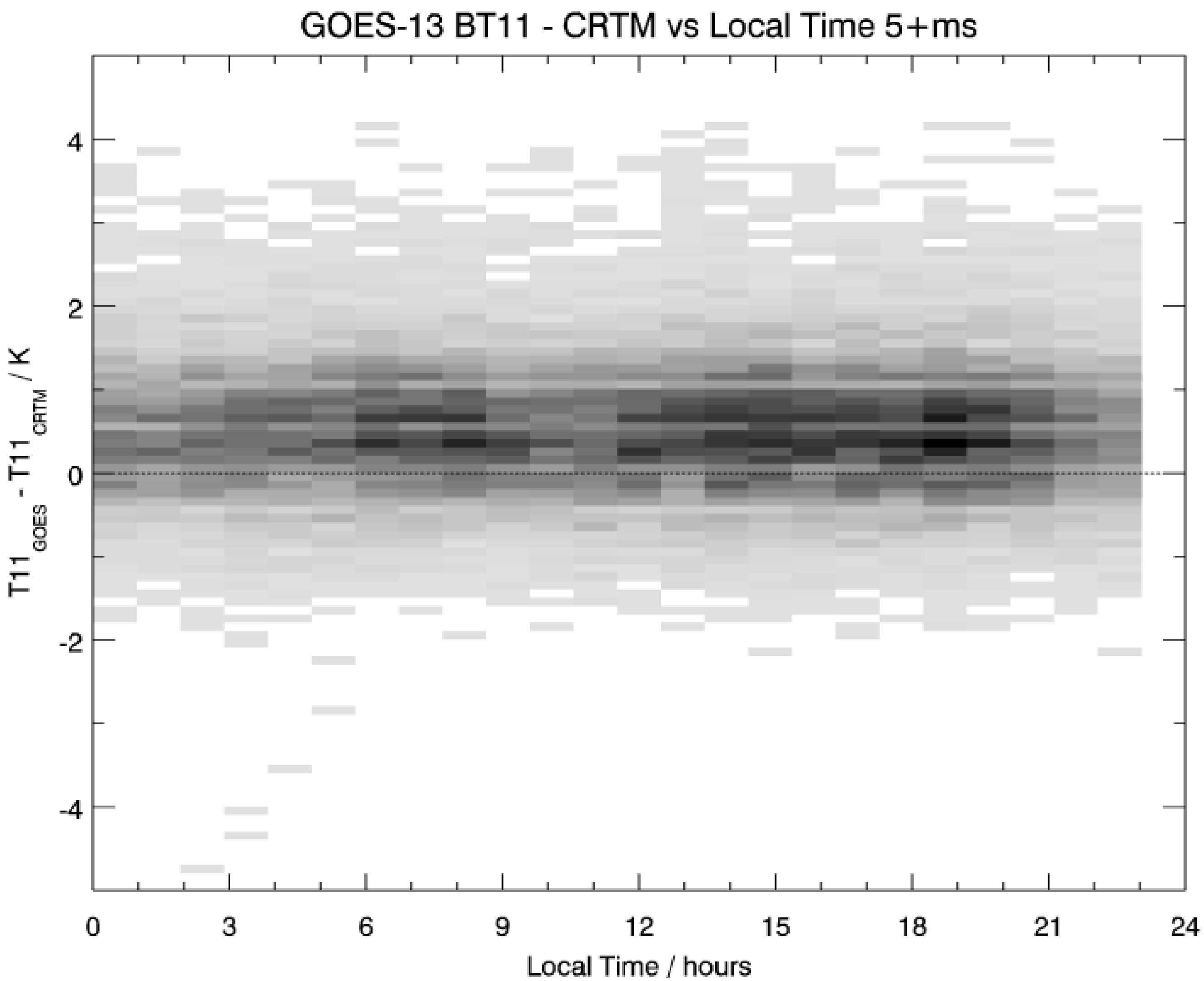

THE CALIBRATION OF GEOSTATIONARY SATELLITES

Jonathan Mittaz
University of Reading

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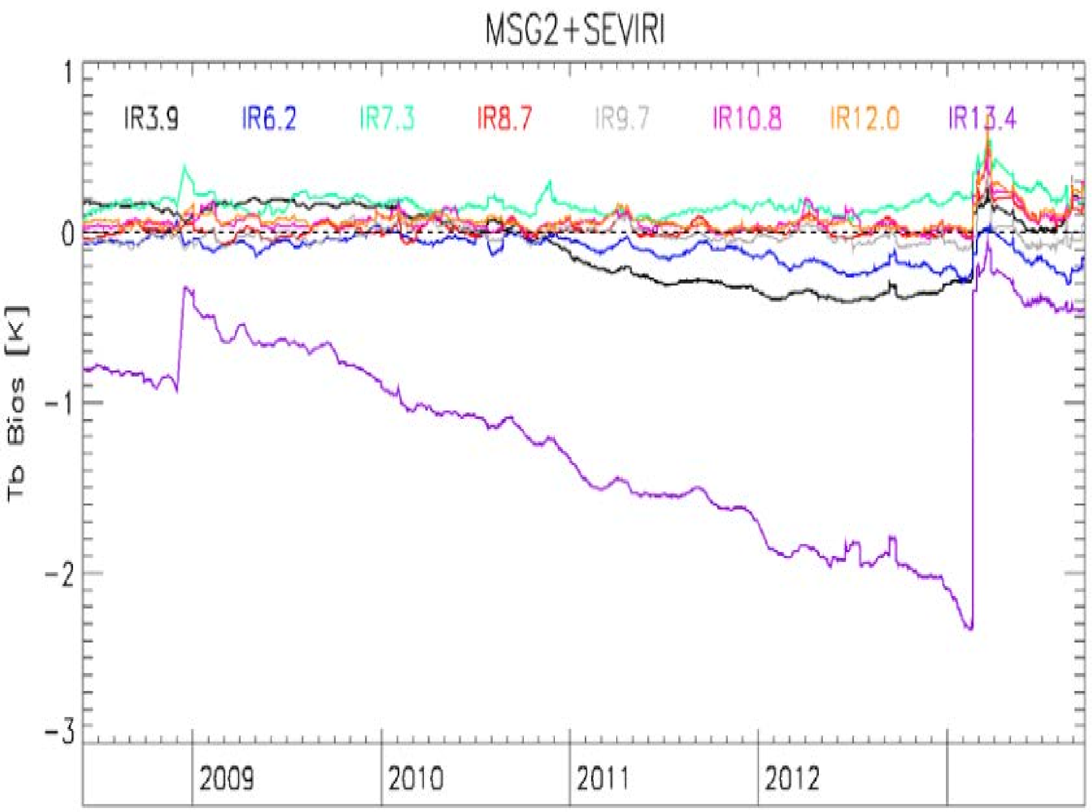
LIMITLESS POTENTIAL | LIMITLESS OPPORTUNITIES | LIMITLESS IMPACT

SEVIRI ISSUES (2)

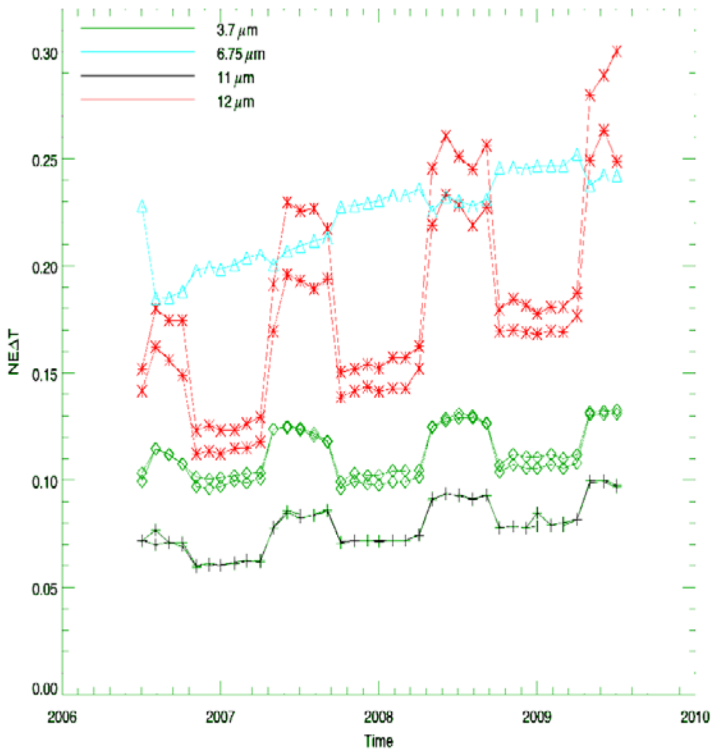
- Ice buildup on 13.4μm channel (Hewison & Müller 2013)

- Based on GSICS analysis
  - Compared to IASI
- Clearly see decontamination events
- Correction available for GSICS period
  - for climate may need to correct for earlier sensors



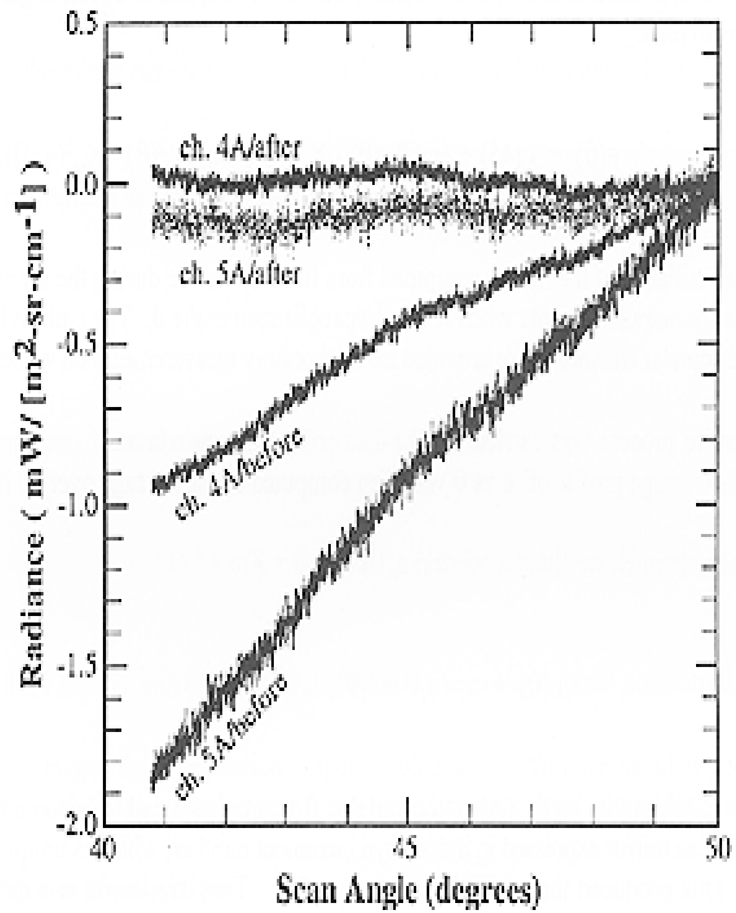
GOES Issues (1)

- Requires two detector temperatures around a year
- Impacts the NeΔT
  - Seasonal variation
- Long term time vari
- Should not assume NeΔT…

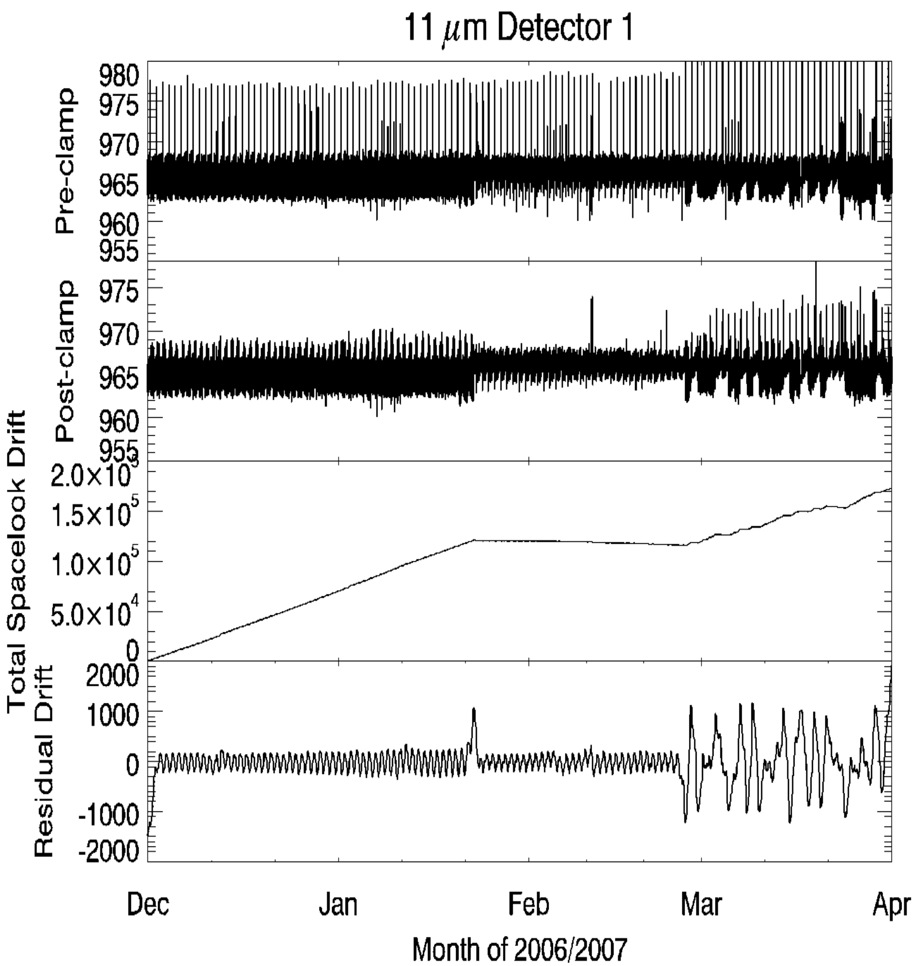


GOES (2) - Mirror emissivity correction

- Paddle mirror means different incident angles for different scan locations
- Change in mirror emissivity
  - Variation in mirror radiance
- Effect up to a few Kelvin across scan
- Correction based on Space view scans



GOES (3) – seasonal calibration problems



Eclipse season

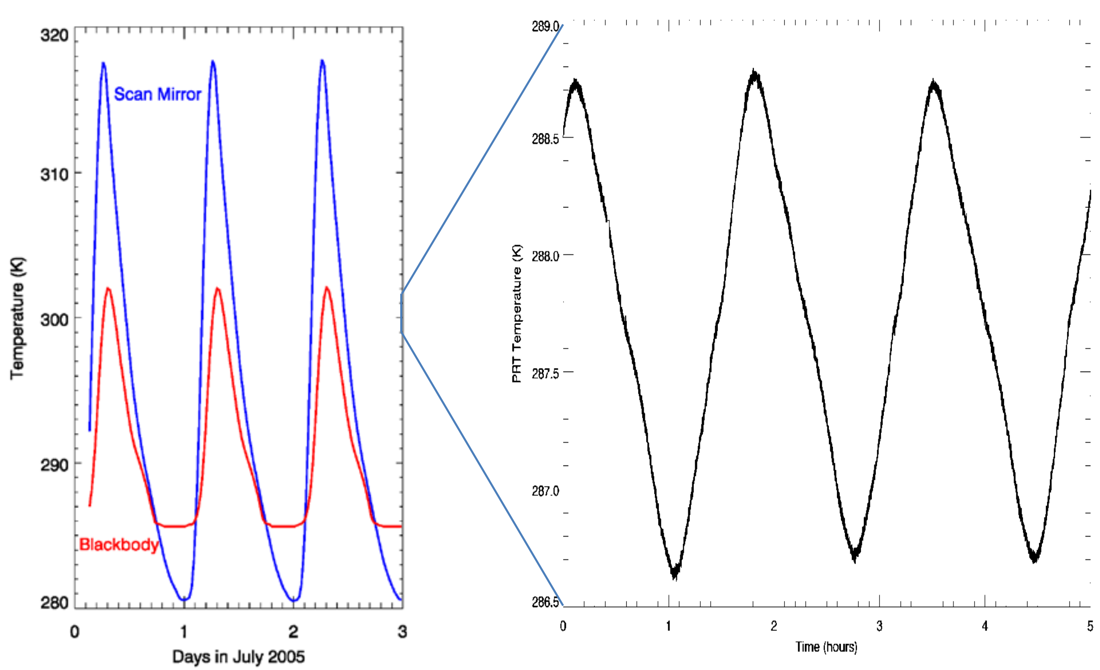
Use accumulated space counts as a proxy for the instrument self-emission radiance

Instrument well behaved until eclipse season (can see diurnal self emission variations)

When eclipse season starts instrument seems to go haywire…

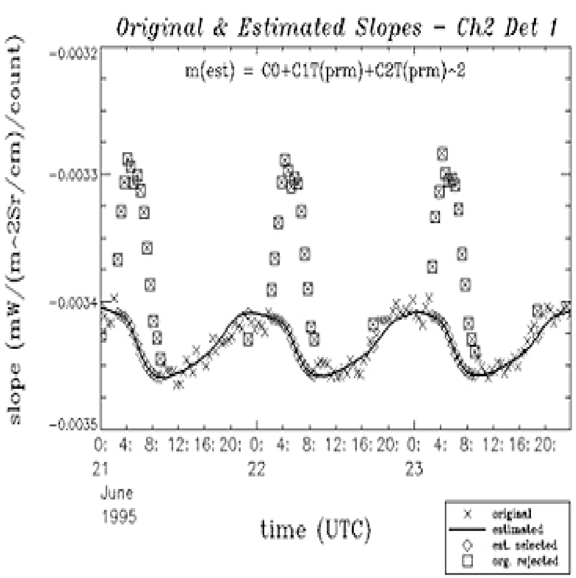
GOES issues (4) – instrument temperatures

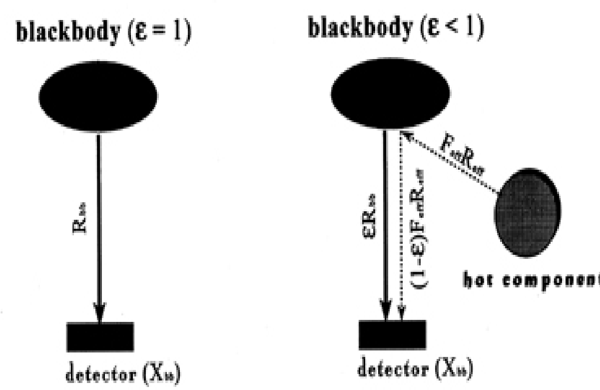
- 3-axis stabilized
  - Large thermal variations compared to LEO satellites



The Midnight Blackbody Calibration Correction (MBCC)

- Corruption of the calibration system around the time of local midnight – stray light from a heated part of the instrument (thought to be the sun shield) reflected off BB





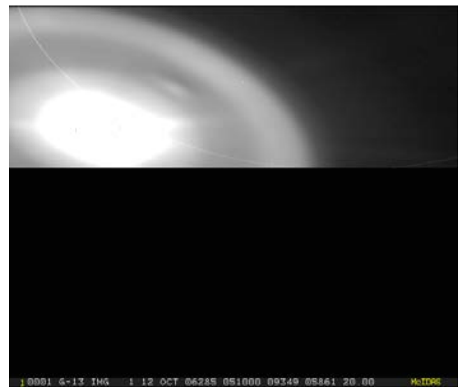
$$m = \frac{R_{bb}}{X_{bb} - X_{sp}}$$

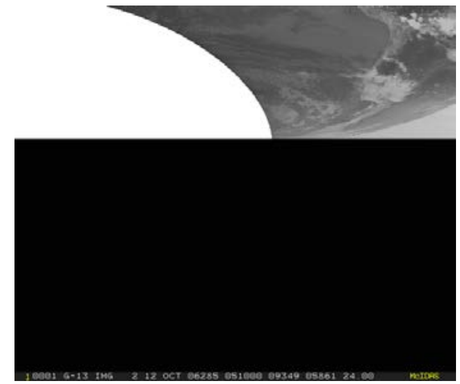
$$m_{true} = \frac{\epsilon R_{bb} + (1-\epsilon) F_{eff} R_{eff}}{X_{bb} - X_{sp}}$$

Solar contamination

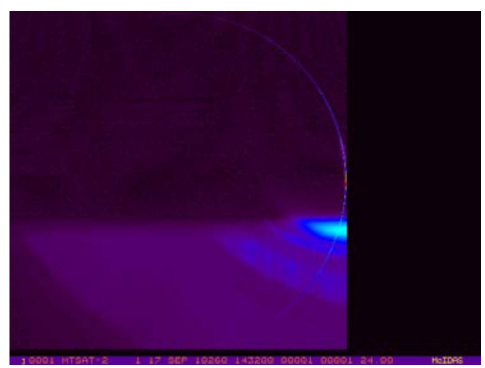
- Solar contamination in the image plane seen close to local midnight
    - Worst can be masked out
    - But still can have residual effects…

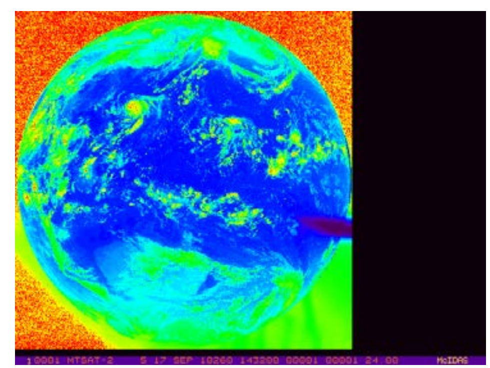
GOES-13





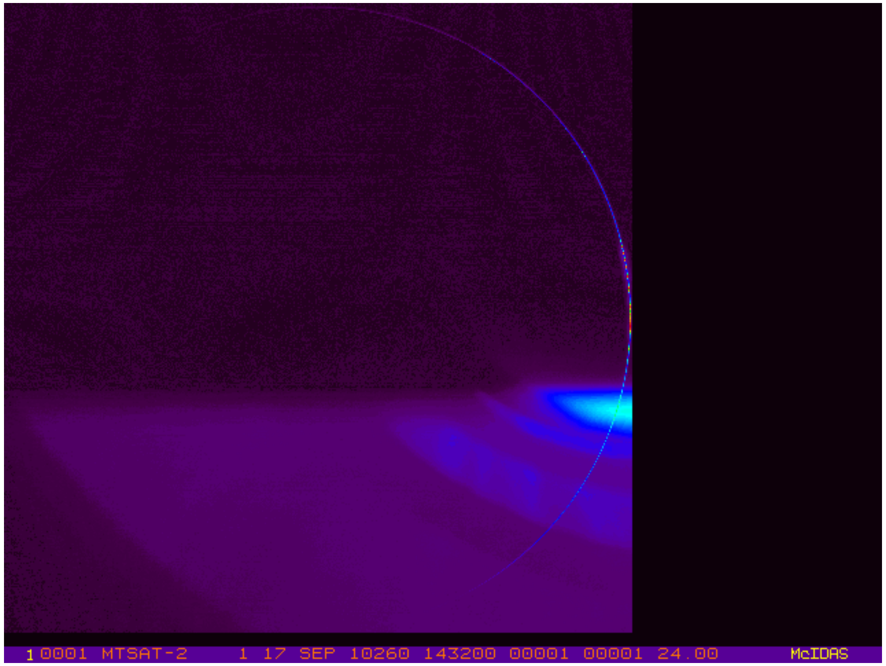
Visible MTSAT-2 3.8µm



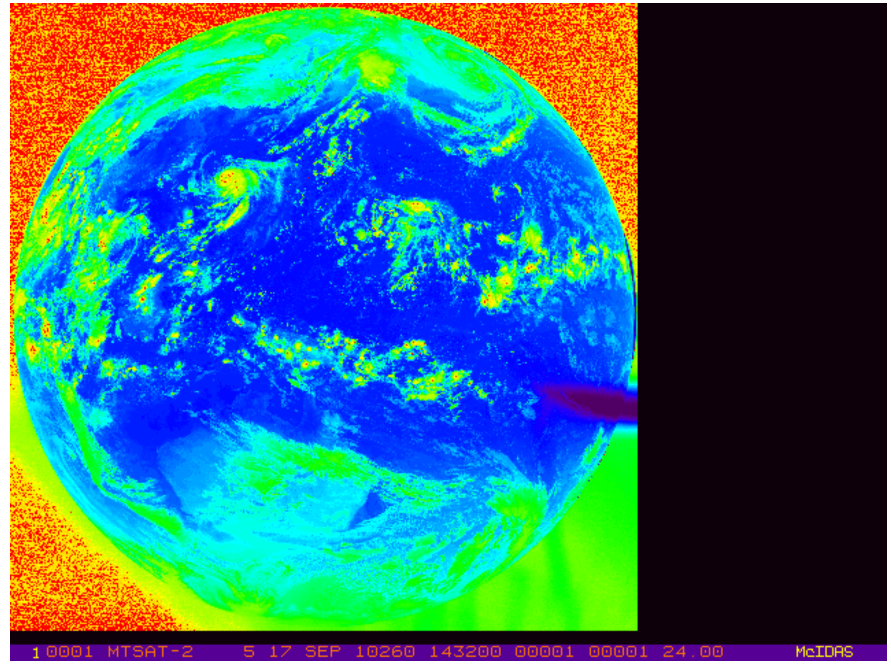


Scattered light in MTSAT-2

Visible channel



3.9 micron channel



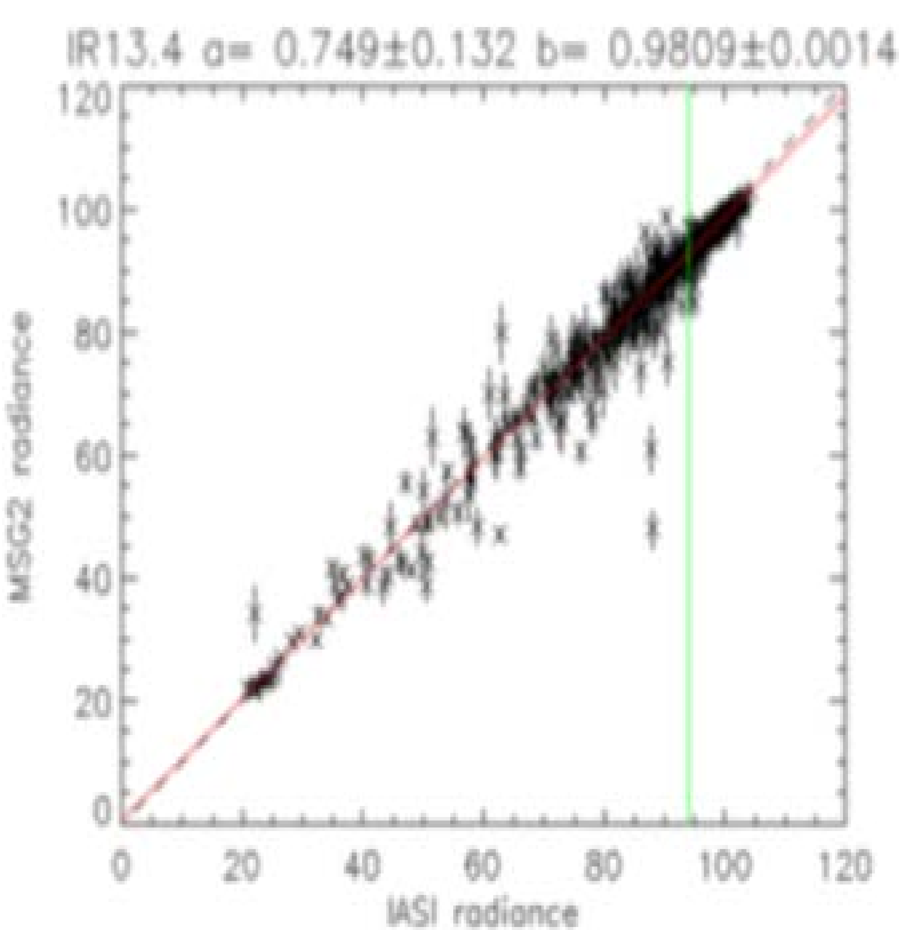
Occurs during eclipse season around local midnight

Calibration fixes

- There are a number of different approaches to fix GEO calibration biases/error
  - GSICS (Global Space-based Inter-Calibration System)
    - Provides scene temperature dependent bias based on a linear model
  - Modification to calibration algorithms and/or recalibration
    - Updated MBCC algorithm
  - Model solar contamination
    - Doesn't work very well…

GSICS + GOES

- Provides a correction to BTs
- Detailed Uncertainty analysis of matchup process applied (e.g. Hewison 2013)
- Ordinary Least Squares fit
  - This may introduce biases due to not taking into account uncertainties in both X & Y ordinates



Wu & Yu, 2013,GOES GSICS ATBD

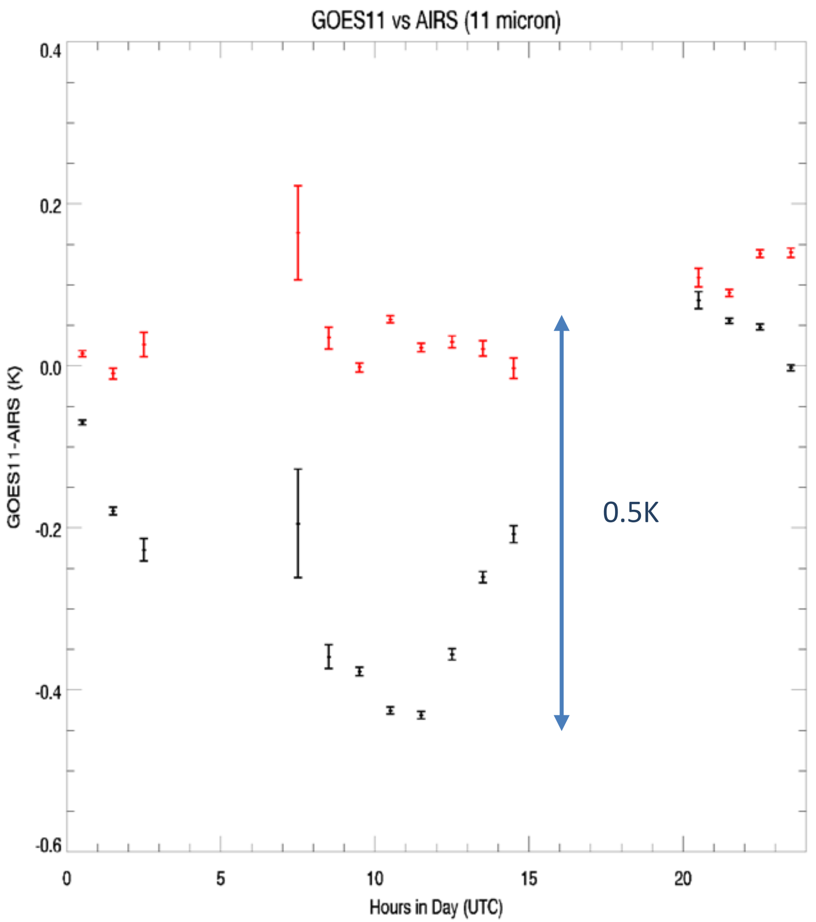
GSICS corrections for goes

- Nightime only data used for correction
- Data averaged over 30 days
  - Midnight effect not corrected for but added to uncertainty (Yu & Wu, 2012, "GSICS GOES-IASI Inter-Calibration Uncertainty Evaluation")

Systematic Error	Ch2(3.9μm)	Ch3(6.5μm)	Ch4(10.7μm)	Ch6(13.3μm)	unit
Radiance bias at standard scenes	0.0047	0.0802	1.7695	1.8216	$mW/m^2/Sr/cm^{-1}$
Tb bias at standard scenes	-0.1928	-0.4455	-1.168	-1.2775	K

Possible Solution: Update MBCC algorithm

- Can correct by updating MBCC
  - Change algorithm on th basis of physical model
- Initial tests indicate can significantly improve calibration
- BUT
  - Currently only theoretical
  - Not included in operations

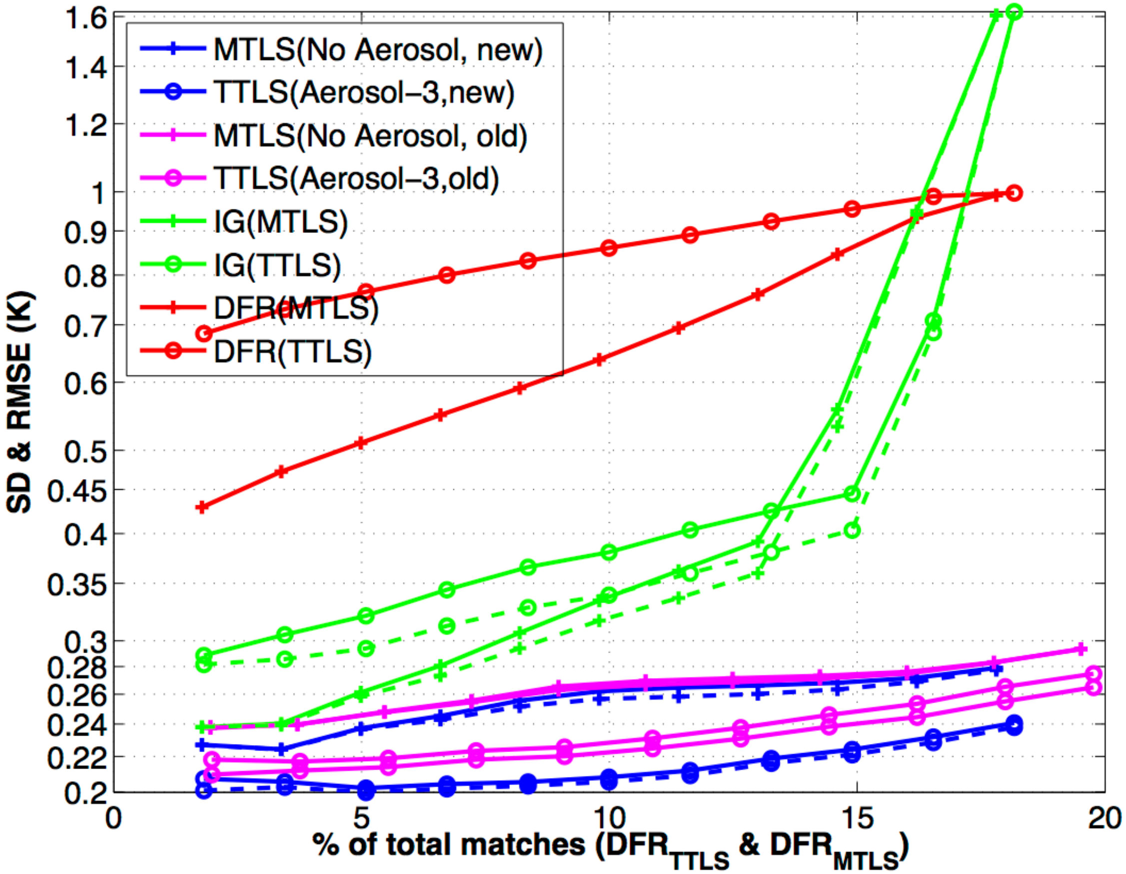


MODIS: Addition of aerosol

- **Put aerosol information in the CRTM**
  - NGAC profiles, multiple species (dust, salt, sulfate, soot)
  - Improve match of RTM to observation
  - Does this improve retrieval?
- **Put aerosol in the retrieval vector**
  - Allow Total Column Aerosol to vary
  - $\boldsymbol{x} = [\mathrm{SST, WV, TCA}]^T$
  - Jacobian now includes ∂T/∂TCA for each channel
  - Does this improve retrieval?
- **MTLS developed for 2-parameter retrieval**
  - Try different regularization operator since problem is now more ill-conditioned: **Truncated Total Least Squares (TTLS)**

$$|\Delta \boldsymbol{y}| \le 1: \ \lambda = (\sigma_{end-1})^2 \qquad |\Delta \boldsymbol{y}| > 1: \ \lambda = (\sigma_{end-1}/\log(|\Delta \boldsymbol{y}|))^2$$

Inclusion of aerosol



- **Accuracy with TTLS & joint [SST, WV, TCA] ~0.2 K**
- **Algorithm sensitivity is also improved *cf.* MTLS**
  - Koner, P.K. & A. Harris, *Remote Sensing*, 2016 (in review)

SST Requirements: Summary

- Accuracy requirements for SST are high
  - <0.1 K (see MODIS example for indication)
- Physical retrievals use forward-modeled BTs
  - Retrievals are dependent on ability to correctly model ToA BTs with appropriate physical relationships
  - Important not to conflate calibration with characterization
- GSICS dataset is very powerful
  - Offers prospect of diagnosing and partitioning error sources
- 3-axis stabilized geostationary imagers have significant calibration issues due to thermal environment
  - Their use in diurnal studies make proper removal of calibration artifacts important