High-Resolution Skin Temperature Derived from Geostationary Satellite Top-of-Atmosphere Clear-Sky Infrared Temperature Retrievals

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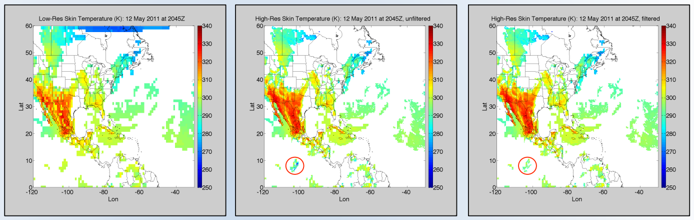
Introduction

The ARM Climate Research Facility Infrared Thermometer (IRT) collects effective ground radiating temperature data at the Solar and Infrared Radiation Station (SIRS) located in the Southern Great Plains (SGP) central facility. NASA Langley provides cloud and clear-sky retrievals for ARM climate modelers using geostationary satellites. Using these retrievals, an inverted correlated-k* method is applied to clear-pixel values of top-of-atmosphere (TOA) infrared temperature in order to derive a large-area, high-resolution skin temperature product (HRTP). The relatively frequent retrievals from geostationary satellites allows for study of the diurnal variation in skin temperature, which is a task not easily accomplished using polar orbiting instruments such as the Moderate Resolution Imaging Spectroradiometer (MODIS) aboard Terra and Aqua. The fine resolution and fact that only clear scenes are used lends to a high-accuracy dataset viable for comparison with the ARM IRT. Higher-accuracy, high-temporal-frequency observations can lead to improved skin temperature measurements and more advanced global climate models.

* R. Goody, R. West, L. Chen, D. Crisp: The correlated-k method for radiation calculations in nonhomogeneous atmospheres. JQSRT, 42 (1989), pp. 539–550.

Background and Methodology

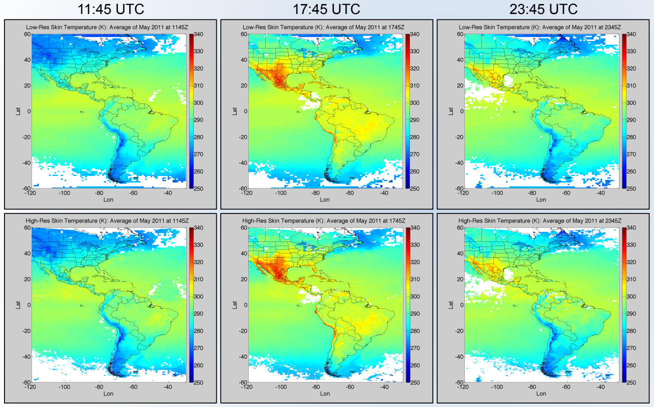
- Start with background atmosphere on 1° x 1° grid from GFS-based model sounding profiles
- Correlated-k radiative transfer scheme used to account for gaseous absorption and bring modeled surface skin temperature to TOA



- Cloud mask and observations used to decide if pixels are clear; mean clear temperature used if > 20% of 1° x 1° box is clear
- **Low-res:** surface skin temperature computed from mean 1° clear temperature correcting for the atmosphere and surface emissivity
  - Emissivity from the Clouds and the Earth's Radiant Energy System (CERES)
- **High-res:** grid the retrieved TOA clear-sky IR temperature (TIRC) into 0.25° x 0.3125° tiles
  - Repeat processing applied to low-res for tiles that are > 20% clear, yields HRTP
  - Filter cold anomalies that arise from cloud mis-identification (see figures)
  - Filter is based on the 99th percentile of the difference between low- and high-resolution skin temperature

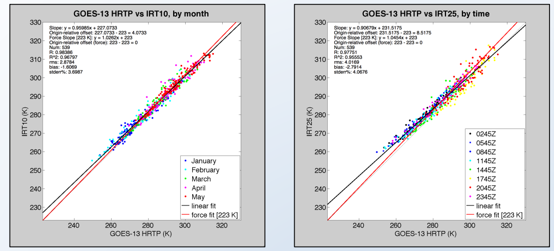
Mean Diurnal Skin Temperatures, May 2011: Effect of Resolution

11:45 UTC | 17:45 UTC | 23:45 UTC

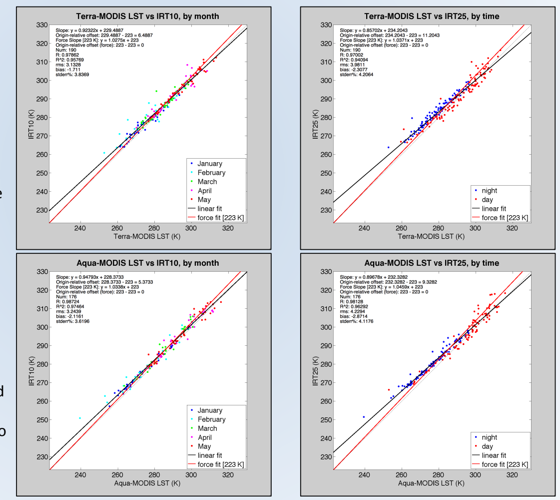


- **Top row:** Low-resolution (1° x 1°) skin temperature (K) from GOES-13-modified GFS data
- **Bottom row:** High-resolution (0.25° x 0.3125°) skin temperature (K), HRTP, derived from inverted correlated-k applied to TIRC
- 3-hourly full disk observations allow for diurnal analysis
  - Eight observations/day
  - Beneficial to modelers
- HRTP warmer by 0.42 K on average

Comparison with SIRS IRT and MODIS Land Surface Temperature: Jan-May 2011



- The upwelling IRT at SGP SIRS records 60-s averaged equiv blackbody brightness temp at 10- and 25-m heights (IRT10 and IRT25)
- 11-µm HRTP for tile nearest the SGP site is compared to IRT10 and IRT25 at the time nearest the GOES full-disk 3-hourly scan, plus an offset needed for scanning time
- HRTP is 1.6 K (2.8 K) colder than IRT10 (IRT25) on average
- Warmer IRT25 on cold end consistent with nocturnal inversion
- Cold tail related to snow in Jan and Feb
- Potential source of error is fact that IRT has no correction for surface emissivity, HRTP uses CERES emissivity maps
- Possible emissivity dependencies on view angle, soil moisture, and vegetation variation not well-classified in HRTP
- Nearest 5-by-5-pixel (1-km pixels) average of Land Surface Temperature (LST) from MODIS compared to IRT reveals Terra-LST is 1.7 K (2.3 K) colder than IRT10 (IRT25), and Aqua-LST is 2.1 K (2.9 K) colder than IRT10 (IRT25), on average
- MODIS generalized split-window LST algorithm uses classification-based emissivity LUT**. Soil moisture and vegetation dependencies well-understood
- The 0.25° x 0.3125° HRTP is comparable to 1-km LST: Can provide up to 96 (15-min) samples per day without adding bias or increasing standard error



- Using regressions forced through the lowest valid IRT temperature (223 K), we can predict HRTP/LST mean ratio with: (IRT10/LST) / (IRT10/HRTP) = HRTP/LST, which is 1.001 and 1.007 for Terra and Aqua LST, respectively, on average (varies diurnally and seasonally)

HRTP/LST Mean Ratio Prediction Demonstration

	IRT10/LST	IRT10/HRTP	Expected HRTP/LST	Confirmed HRTP/LST	# of 3-way matches
Terra	1.0286	0.99508	1.034	1.034	24
Aqua	1.0361	1.0215	1.014	1.014	20

** Snyder, W. and Z. Wan, "BRDF models to predict spectral reflectance and emissivity in the thermal infrared," IEEE Trans.Geosci. Remote Sens., vol. 36, no. 1, pp. 214-225, 1998.

Conclusions/Future Work

- The large spatial scale and high temporal frequency of this product are ideal for climate modeling
- HRTP values comparable to Terra (Aqua) measurements at SGP site to within 0.1% (0.7%) on average
- Address cloud mis-identification for each 4-km pixel, as the influence is more significant at the higher resolution
- Apply correlated-k method on the pixel-level along with finer-resolution model sounding data from GMAO GEOS-5
- Examine sensitivities to surface emissivity and solar azimuth angle using GOES-E and GOES-W
- Develop VAP skin temperature for ARM domains

This work was supported by the DOE through the ASR under Interagency Agreement DE-SC0000991/003, the NOAA Climate Data Records Program, and the NASA Earth Science Mission Directorate through the CERES Project.

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