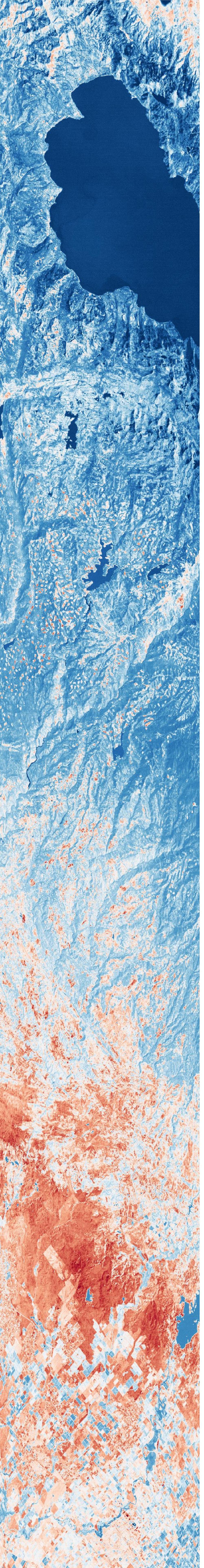

A Unified and Coherent Land Surface Temperature and Emissivity Earth System Data Record (ESDR) for Earth Science Research

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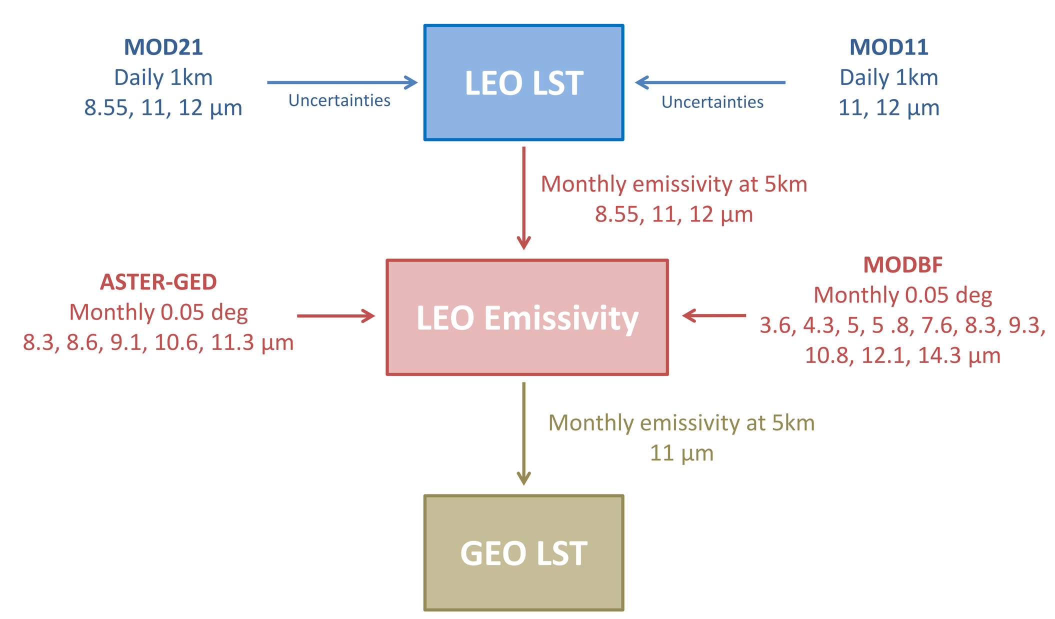
Introduction

NASA has identified a major need to develop long-term, consistent products valid across multiple missions, with well-defined uncertainty statistics addressing specific Earth science questions. These types of data sets are termed Earth System Data Records (ESDRs) and are defined as long-term, well calibrated and validated data records for Earth Science research. Land surface temperature and emissivity (LST&E) data have been identified as an important ESDR by NASA and many other international organizations, e.g. GCOS. LST&E data are essential for a wide variety of surface-atmosphere studies, such as surface evapotranspiration and atmospheric water vapor profiles retrieval. LST&E products are currently generated from sensors in Low Earth Orbit (LEO) such as the NASA-EOS MODIS instruments on the Terra and Aqua satellites as well as from sensors in Geostationary Earth Orbit (GEO) such as GOES. Sensors in LEO orbits provide global coverage at moderate spatial resolutions (~1-km) but more limited temporal coverage (twice-daily), while sensors in GEO orbits provide more frequent measurements (hourly) at lower spatial resolutions (~3-4 km) over a geographically restricted area. LST&E products from these instruments are currently produced using different emissivity and atmospheric corrections, and usually do not include a full set of uncertainty metrics. NASA has recognized this general lack of consistency between science products and has identified the need to develop long-term, consistent, and calibrated data and products that are valid across multiple missions and satellite sensors. We address this problem by generating three self-consistent LST&E ESDRs from 2000-2018 with well defined uncertainties: 1) a unified global LEO LST-ESDR at 1-km spatial resolution and resampled to daily, 8-day and monthly; 2) a unified N. and S. America GEO LST-ESDR at 5-km spatial resolution and resampled to hourly temporal resolution; 3) a unified global Land Surface Emissivity (LSE) ESDR at 5-km spatial resolution and monthly temporal resolution.

Unified and consistent LST and emissivity ESDR



Key Milestones

Item	Date	Comments
Project start	02/2014	
Deliver ATBD	08/2015	
Start processing of ESDRs	02/2016	
1st set of data products (with source code, documentation, and ancillary data)	08/2016	LEO datasets over North America
2nd set of data products	08/2017	LEO datasets for the globe and the GEO datasets for one year
3rd set of data products	08/2018	Full GEO datasets and LEO 8-day and monthly composites
Complete data transfer to DAAC	01/2019	

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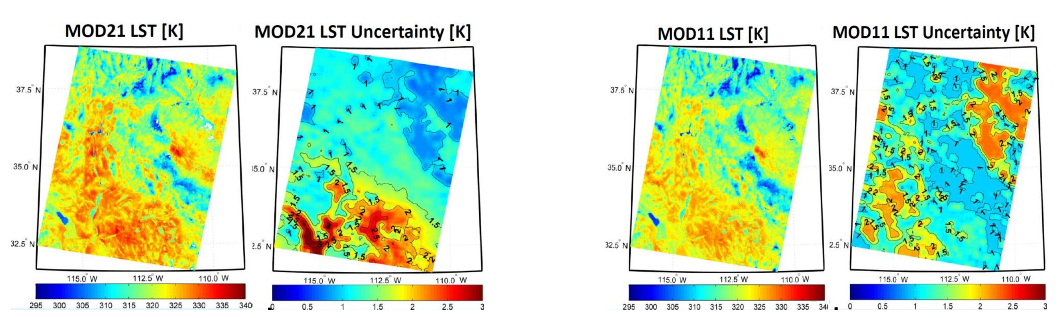
A Unified LEO LST ESDR

LST from MODIS are derived from either Split-Window (SW) or Temperature Emissivity Separation (TES) approaches. SW products (e.g. MOD11) have high accuracy over graybody surfaces (water, vegetation, ice, snow) but large uncertainties over arid and semi-arid regions, while in contrast TES products (e.g. MOD21) have high accuracy over arid regions.

LEO LST is produced by combining the MODIS MOD11/MOD21 LST products using an uncertainty analysis approach

- Globally at 1 km spatial resolution
- Daily, 8-day and at monthly time step from 2000 to 2018

Methodology

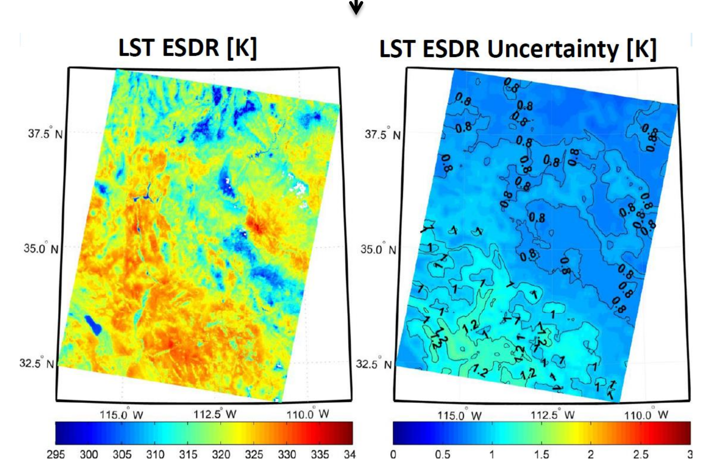


$$\delta LST_{MOD} = a_0 + a_1 TCW + a_2 VZA + a_3 TCW\ VZA + a_4 TCW^2 + a_5 VZA^2$$

with a_i regression coefficients dependent on surface type; TCW Total Column Water (cm) from MOD07 or NCEP; VZA Sensor View Zenith angle

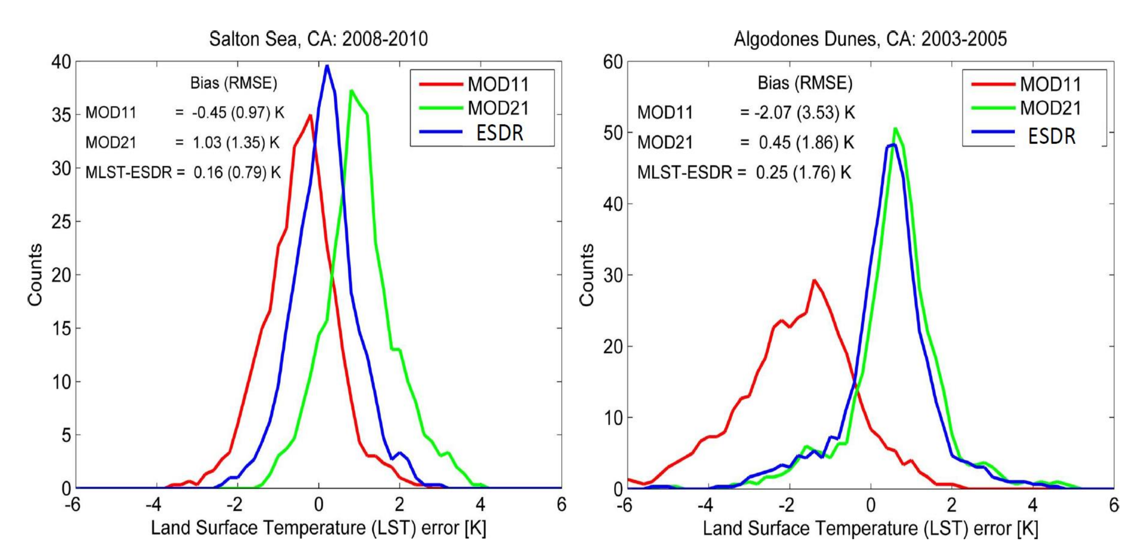
$$LST_{ESDR} = \frac{1}{(w_{MOD11} + w_{MOD21})}(w_{MOD11} LST_{MOD11} + w_{MOD21} LST_{MOD21})$$

with $w_{MOD} = 1/\delta LST_{MOD}$



Validation

Validation over a water site (Salton Sea, CA) using in situ radiometer measurements coincident with MODIS observations from 2008-2010, and using a radiance-based method at the Algodones dunes in CA from 2003-2005



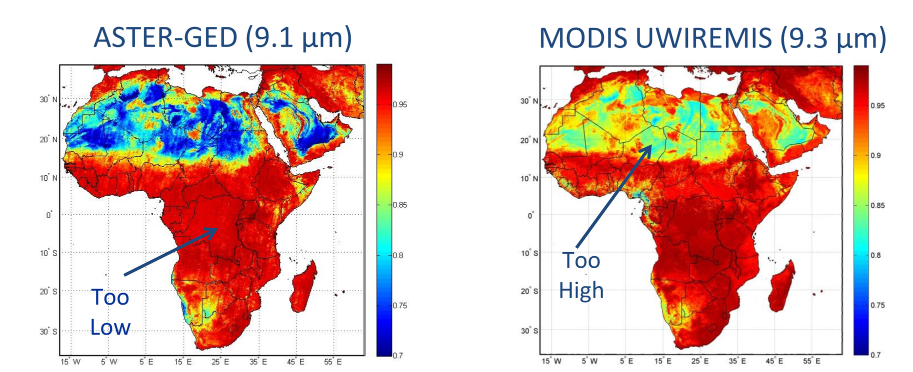
Uncertainty of unified LST ESDR is lower than either of the original inputs since a 'conjunction' of probabilities of each product's uncertainty is calculated

A Unified LEO Emissivity ESDR

Land surface Emissivity from Low Earth Orbit (LEO) sensors such as MODIS and ASTER on Terra are produced at different spatial, spectral and temporal resolutions, and using different retrieval algorithm approaches, which limits their combined use in atmospheric profile retrieval algorithms and data assimilation.

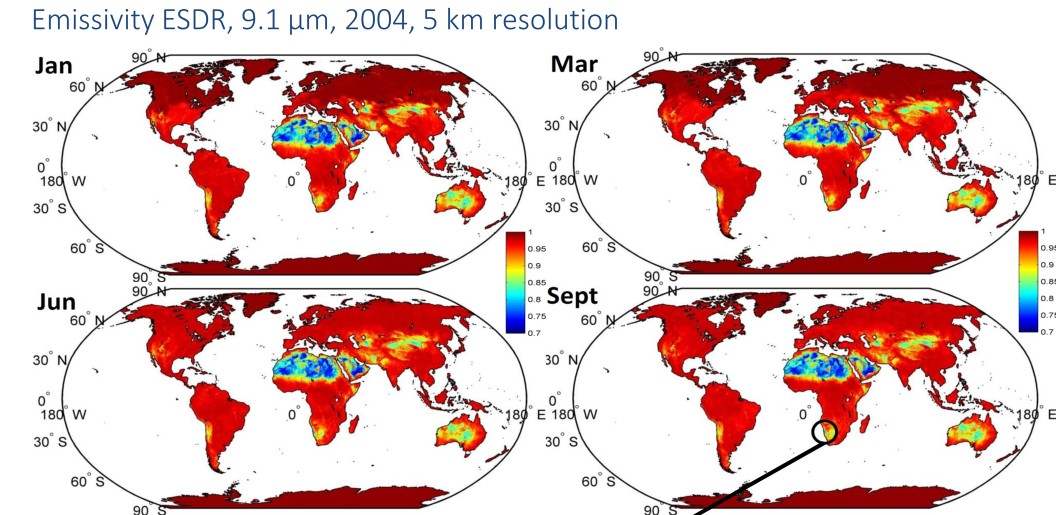
LEO emissivity database is produced by merging the MODIS baseline-fit emissivity database (UWIREMIS) and the ASTER Global Emissivity Database (ASTER GED). Product includes 12 bands from 3.6 to 14.3 µm and is extended to 417 bands using a Principal Component (PC) regression approach

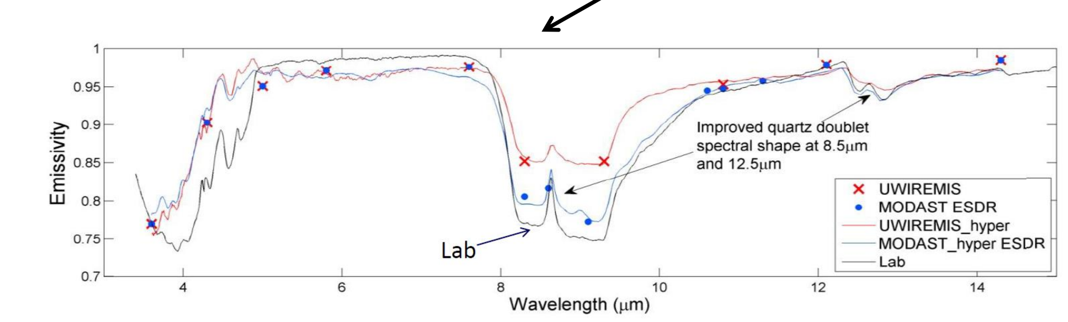
- Globally at 5km spatial resolution
- Monthly time-step



Methodology

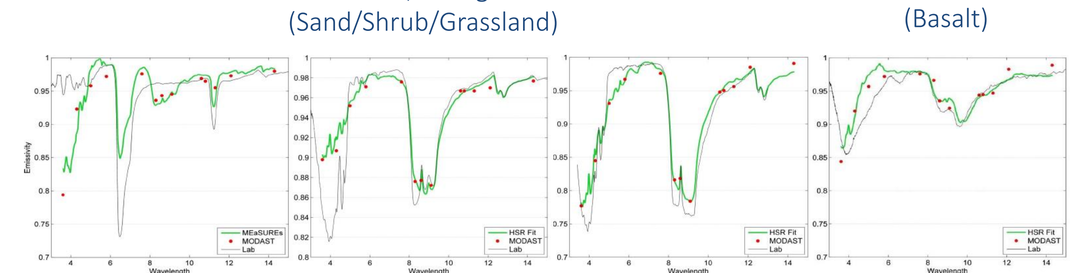
- Aggregate ASTER GED 100 m to 5 km (consistent with UWIREMIS)
- Adjust the ASTER GED climatology on monthly time-steps to account for seasonal changes in vegetation and snow cover
- Merge 5 ASTER band with the 10 UWIREMIS band LSE and extend to high spectral resolution using a (PC) regression approach.





Validation

Comparison with laboratory measurements

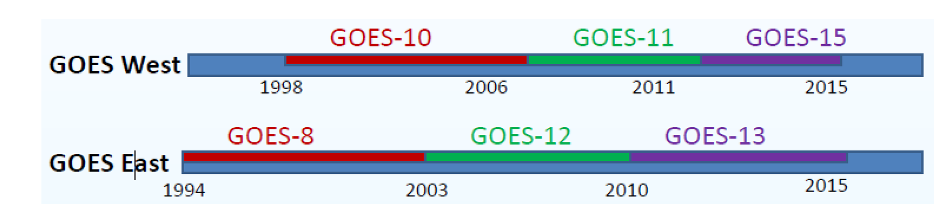


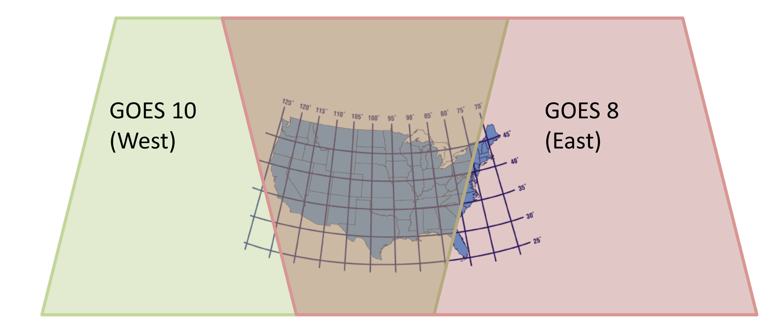
A Unified GEO LST ESDR

Currently no standard, consistent GOES LST Product exists for GOES satellites 8-15 (2000 – present). A consistent GOES LST data record with known uncertainties would be highly beneficial to satellite-based surface energy balance models (e.g. ALEXI) that calculate evapotranspiration, data assimilation in weather models (e.g. NCEP) and in climate studies related to the diurnal temperature cycle.

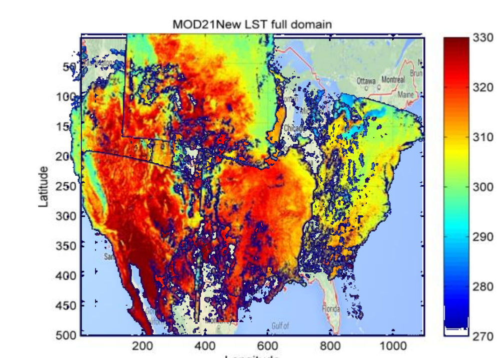
GEO LST will be produced using a single-channel retrieval algorithm. The unified LEO emissivity ESDR is used by the algorithm to ensure consistency between all GOES data. The LEO LST ESDR is used to normalize the GOES LST

- 5 km spatial resolution
- hourly time step from 2000 to 2018 over North America and a 3-hourly time step over South America

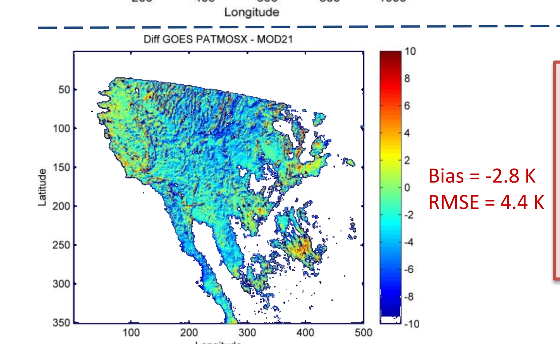




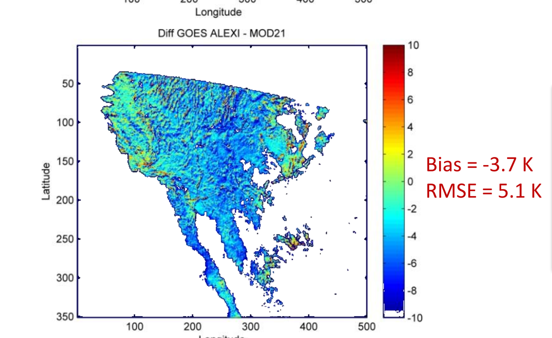
Existing algorithms comparison



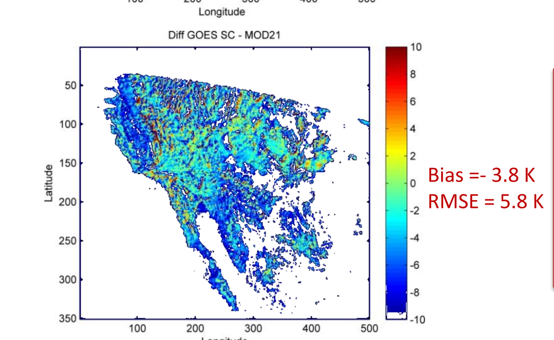
Refrence: MODIS MOD21 LST
- Method: **TES algorithm**
- Atmospheric correction: **RT simulations** (NCEP profiles)
- Emissivity values: **outputs**



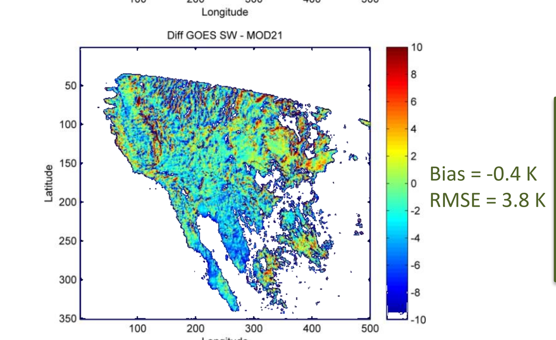
PATMOSX (GOES East + West)
- Method: **Single chanel**
- Atmospheric correction: **RT simulations** (NCEP CFSR)
- Emissivity values: **CLAVR-x/SEEBOR database**



Alexi (GOES East + West)
- Method: **Single chanel**
- Atmospheric correction: **RT simulations** (NARR/CFSR profiles)
- Emissivity values: **0.98 (fixed value)**



UMD (GOES East)
- Methods: **Single chanel**
- Atmospheric correction: **RT simulations** (GOES Water vapor channel)
- Emissivity values: **according to IGBP types**



UMD (GOES East)
- Methods: **Split Window 11&12 µm**
- Atmospheric correction: **Yes** (Generalized Split-Window)
- Emissivity values: **IGBP types**