# Air Force Research Laboratory

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# Challenges in performing an in-flight absolute radiometric calibration

Atmospheric Transmission Models/
Modeling in Remote Sensing Meeting
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AFRL

# Outline

- Acronyms
- In-flight absolute radiometric calibration
- Greenland campaign
- MODTRAN parameterization
  - Sources of data
  - Challenges
- Benchmarking results
- Acknowledgments

# Acronyms

- AERONET: Aerosol Robotic Network (global network of CIMEL sun photometers)
- AIRS: Atmospheric Infrared Sounder
- ARC: NASA-Ames Research Center
- ASTER: Advanced Spaceborne Thermal Emission and Reflection Radiometer
- AVHRR-2: Advanced Very High Resolution Radiometer
- GIMP: Greenland Ice Mapping Project
- GLAS: Geoscience Laser Altimeter System
- GSFC: NASA-Goddard Space Flight Center
- ICESat-2: Ice, Cloud, and land Elevation Satellite
- MR: meteorological range
- NICESpecS: Non-imaging snow and ICE spectrometer Suite
- RT: radiative transfer
- SPOT-5: Satellite Pour l'Observation de la Terre (France)

# Absolute radiometric calibration

- In-flight or on-orbit (airborne or satellite sensor)
- Use of *in situ* measurements to constrain a RT code input parameters
- At-sensor radiances are benchmarked against RT predicted
- Part of optical/thermal closure before “L2/L3/L4” products can be derived
- Implemented on temporal scale relevant to sensor

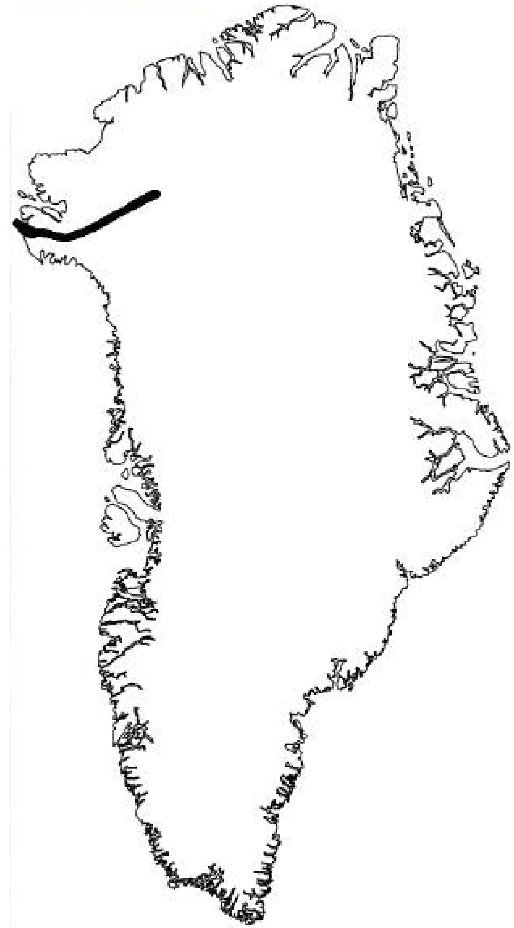
# 2015 Greenland campaign

- NASA-HQ funded campaign:  coordination of two aircraft based out of Thule AB
- NICEspecS – piggyback to prime instruments
- Purpose:  ICESat-2 algorithm development
- Areas of interest:  Greenland ice sheet and Arctic Ocean sea ice during the summer melt season (July and August)

# Geospatial context

# 29 July 2015 flight line

Image: NASA/TM-2015-217544, Greenland 2015 Flight Report



# MODTRAN parameterization

- Apparent reflectance of accumulated ice and bare rock targets
- $CO_2$ (AIRS)
- Meteorological range (CIMEL)
- $O_3$ (CIMEL)
- Spectral aerosol extinction and absorption based on Ångstrom exponents (CIMEL)
- Columnar water vapor
  – Ice: Aqua MODIS L3 gridded
  – Rock: CIMEL
- Target elevation (GIMP)

| parameter | default | input |
|---|---|---|
| CO2 (ppmv) | 299.900 | 396.800 |
| O3 (DU) | 343.760 | 310.270 |
| H2O (cm) | 1.701 | 0.858 (r) |
| | | 0.387 (i) |
| MR (km) | 46.810 | 67.270 (r) |
| | | 95.480 (i) |

# Apparent reflectance (ρ)

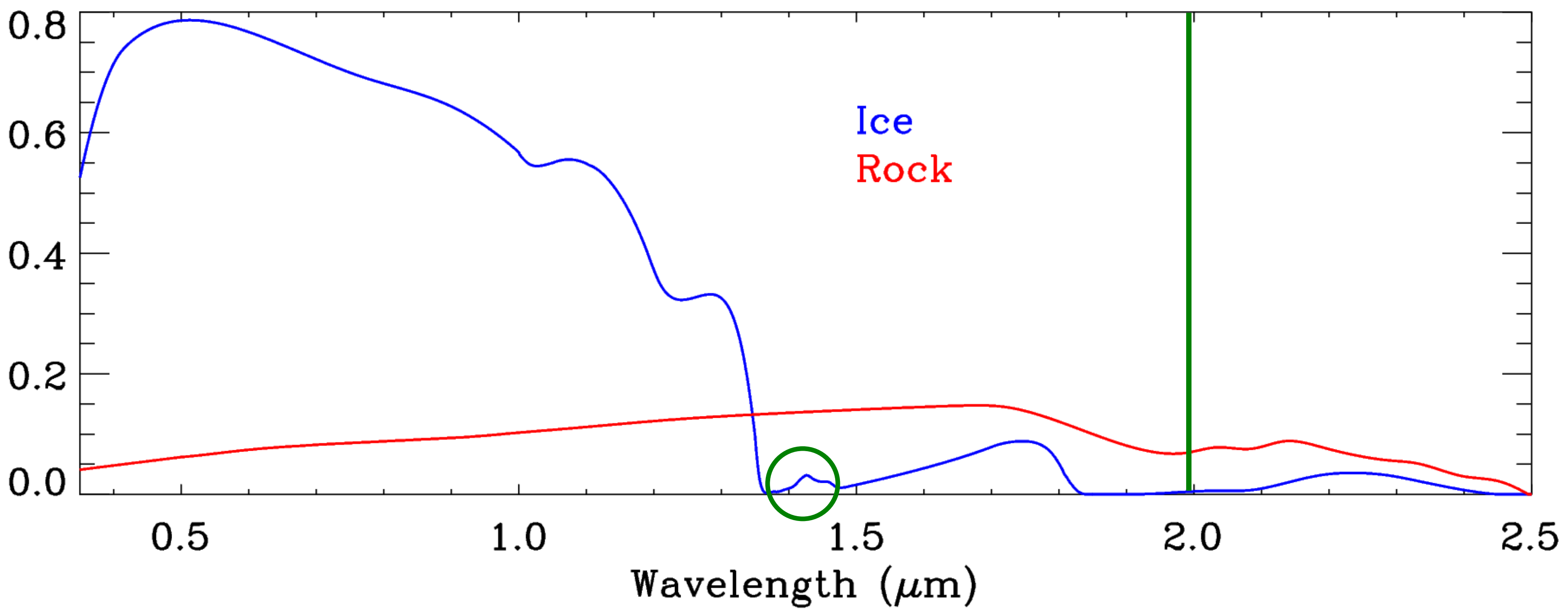
$$\rho_\lambda = (\pi L_\lambda d^2) / (Eo_\lambda \cos(\Theta))$$

$\rho$ = apparent reflectance
L = NICESpecS radiance
d = sun earth distance in au (1.015325)
Eo = TOA irradiance (Kurucz 2005)
$\Theta$ = solar zenith angle (ice = 57.84º/rock = 58.07º)

# Bare rock digital image

Thule Supergroup
- Tonalitic to granitic orthogneiss
- Neoarchaen to Mesoarchaen intrusive rock (metamorphosed)

# Apparent reflectance spectra



# Thule CIMEL site

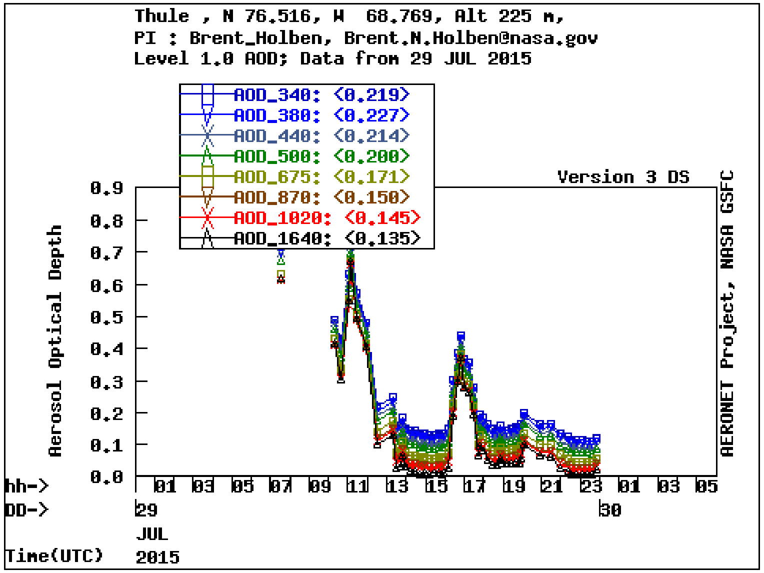
Thule Air Base (Pituffik)
76.5161° N 68.7690° W
Elv: 225 m

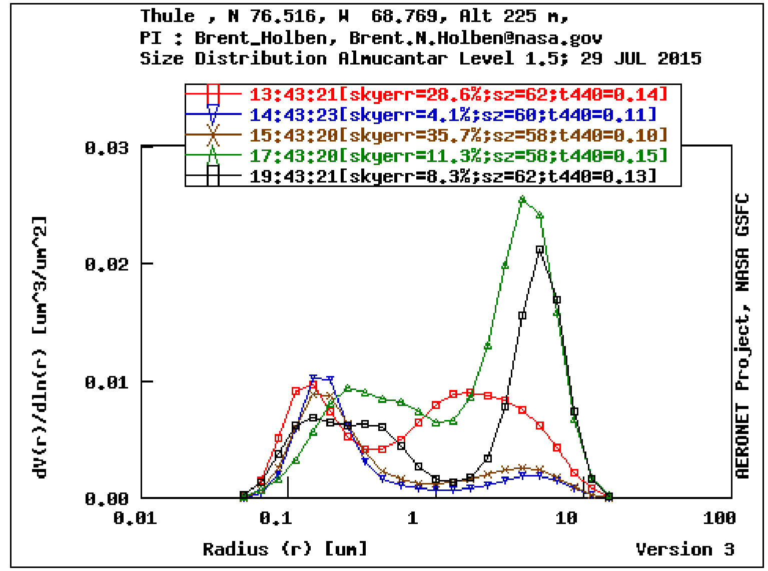
Photos: AERONET Thule web page

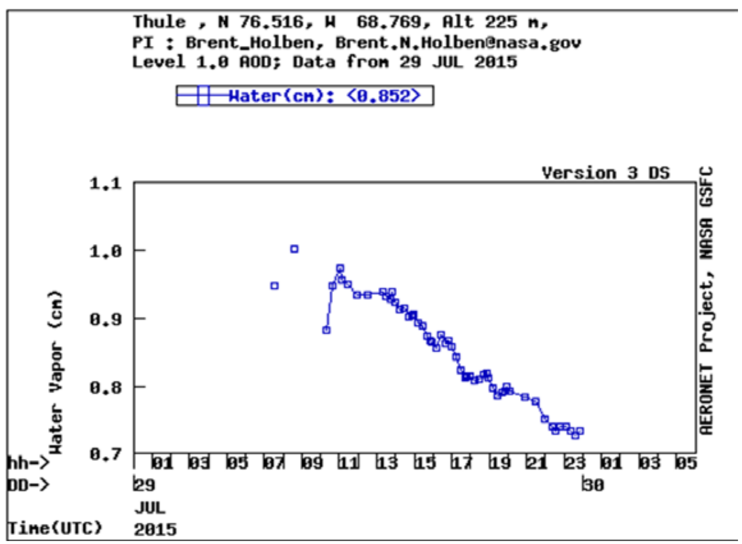
# CIMEL sun photometer products

- Spectral AOD (340, 380, 440, 500, 675, 870, 1020 nm)
- Aerosol extinction and absorption coefficients (integrated)
- ω (single scattering albedo)
- P(Θ): total, coarse, and fine mode phase functions
- *g* (asymmetry factor)
- Size distribution
- Columnar water vapor
- Spectral refractive indices (real and imaginary)
- Upward/downward and diffuse flux, radiative forcing (BOA, TOA)
- Ångstrom exponents

# 150729 CIMEL data



# Challenges

Assumption of horizontal homogeneity

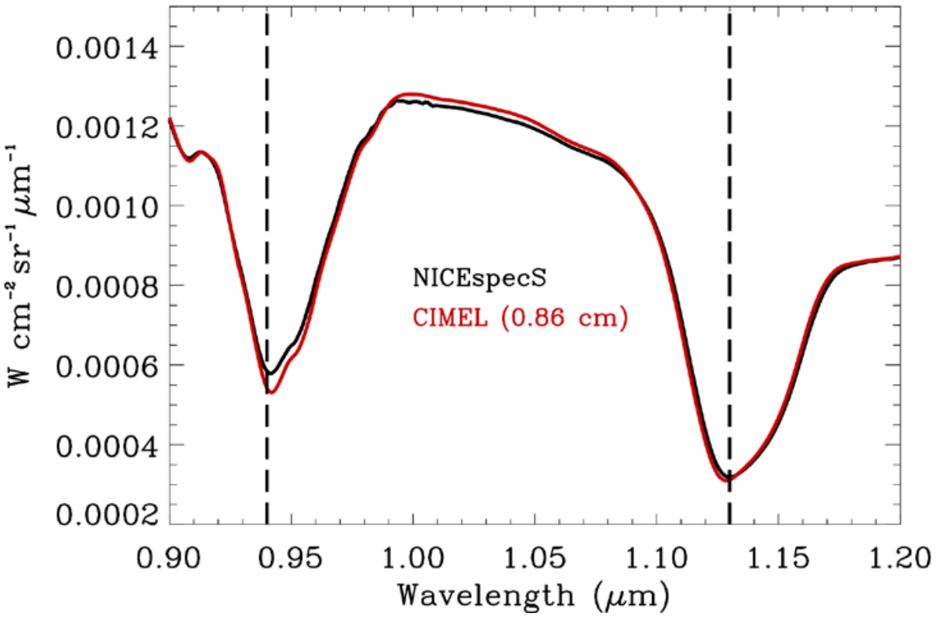
| Target | Lat | Lon | UTC | Distance to CIMEL (km) |
|---|---|---|---|---|
| Rock | 76.720112 | -67.723937 | 17.0064 | 54.217 |
| Ice | 77.095845 | -63.239045 | 16.6835 | 156.346 |

Spatial scaling issues

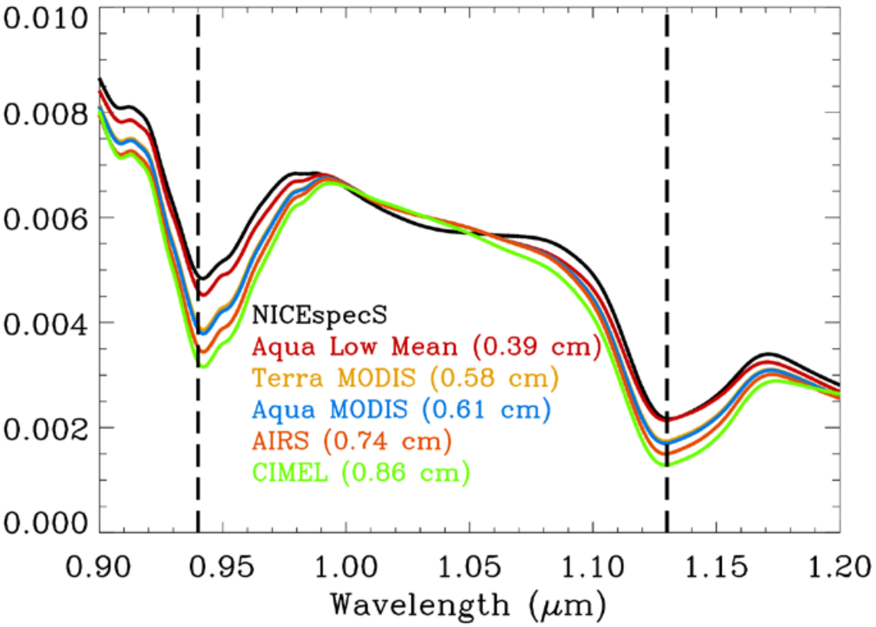
| WV source | Spatial footprint | Distance from ice target (km) |
|---|---|---|
| CIMEL | Point | 156.346 |
| AIRS | 2.3 km | 24.130 |
| Terra/Aqua MODIS L3 gridded | $1^{o}$ x $1^{o}$ | 44.607 |

# Challenge: water vapor

Rock




Ice



# Challenge: DEM for a changing environment

- GIMP
  - Temporal coverage: 2003-2009
  - Compilation multiple sensors
    - ASTER and SPOT-5 DEMs (ice sheet periphery and margin)
    - AVHRR-2 photoclinometry (interior and far north)
    - Data calibrated to approximate mean ICESat/GLAS elevations
  - Spatial resoln: 30 m
  - Establish benchmark data sets for observing ice sheet change and stability

| Target | UTC | Elevation (km) | A/C alt (km) |
|---|---|---|---|
| Rock | 17.0064 | 0.462 | 3.8429 |
| Ice | 16.6835 | 1.636 | 2.2339 |

# Other challenges

- Time domain
  - GPS or UTC?
  - Applanix: GPS
  - All other time stamps: UTC
  - Correction factor
  - Offsets in data collection (closest value)
- Solar zenith angle (apparent reflectance calculation)
  - Latitudes (> 72N or < 72S): accuracy may be lower due in part to the effects of atmospheric refraction

# Benchmarking

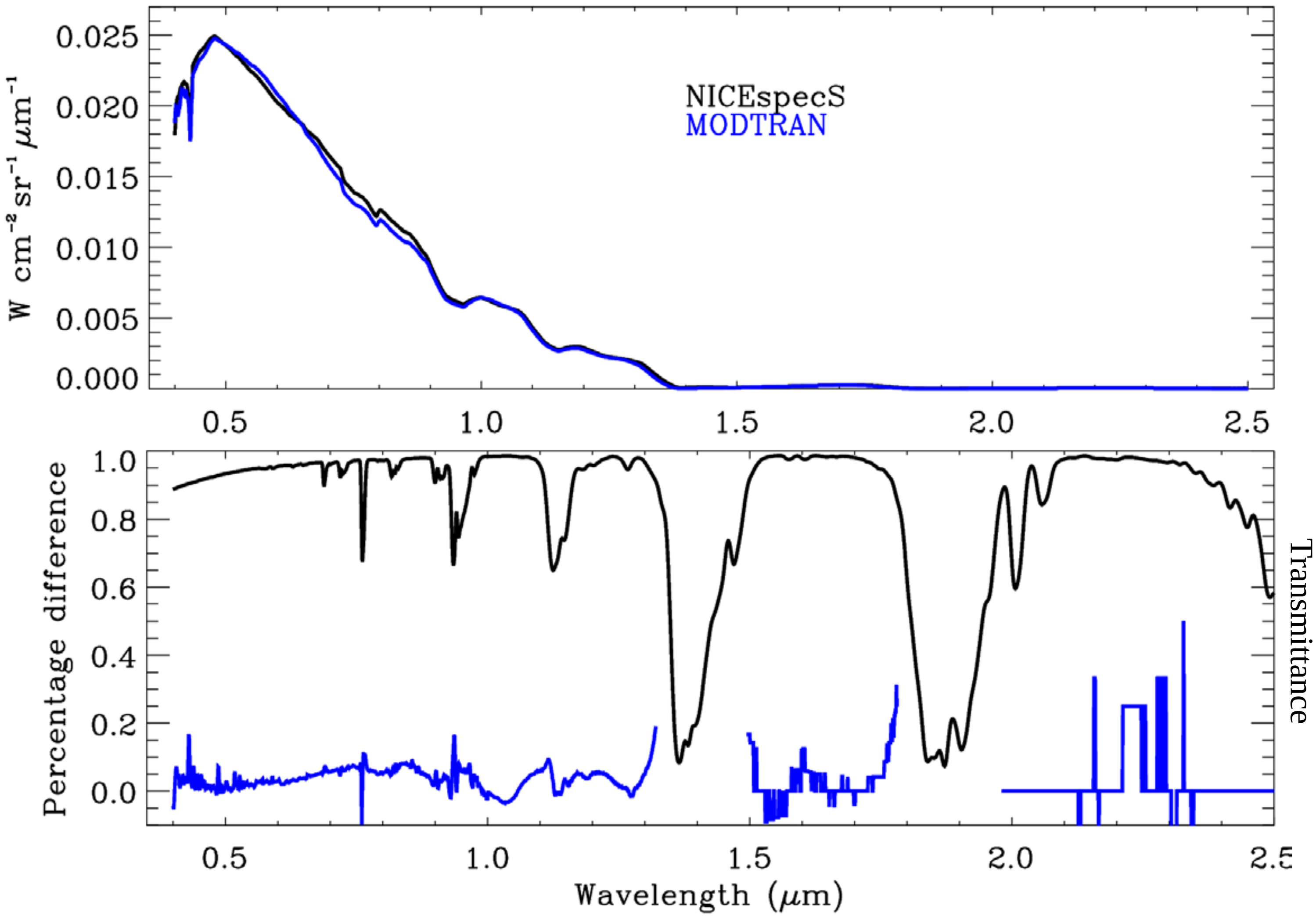
- Percentage difference = (measured-modeled)/modeled

$$PD = (L_{NICESpecS} - L_{MODTRAN}) / L_{MODTRAN}$$

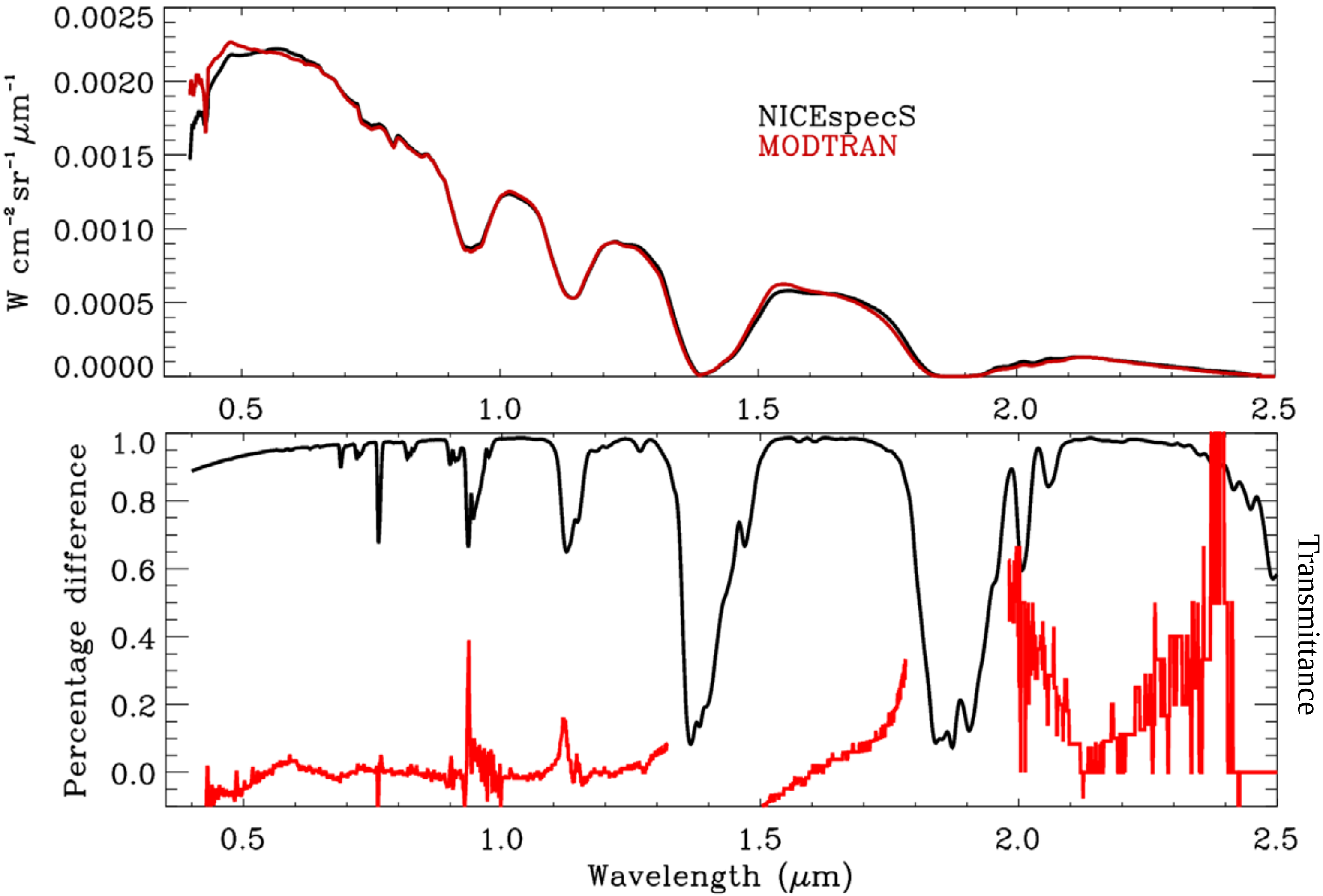
where $L$ = radiance

- Radiances within atmospheric windows used

# Ice comparison



# Rock comparison



# Summary

- Ice overall agreement between measured and modeled radiances within the atm windows:  2.9%
- Rock (dark target) extremely difficult case
  - Overall agreement within 7%
  - Biggest differences are in 2.0-2.5 μm region
- Sources of error
  - All challenges are potential sources of error
  - Spatial and temporal scaling factors
- Another validation case for MODTRAN
- Importance to Landsat calibration and ultimately surface reflectance products used by AF terrestrial weather processing chains

# Acknowledgments

- AERONET family (GSFC)
  – Brent Holben, Thule PI
- Rose Dominguez (ARC)
- Kuma and Big Red van den Bosch

"Always make progress." Mous Chahine (AIRS)