Measurements of the Moon's Infrared (4 – 15 μm) and Microwave (1.6 – 13 mm) Thermal Radiation

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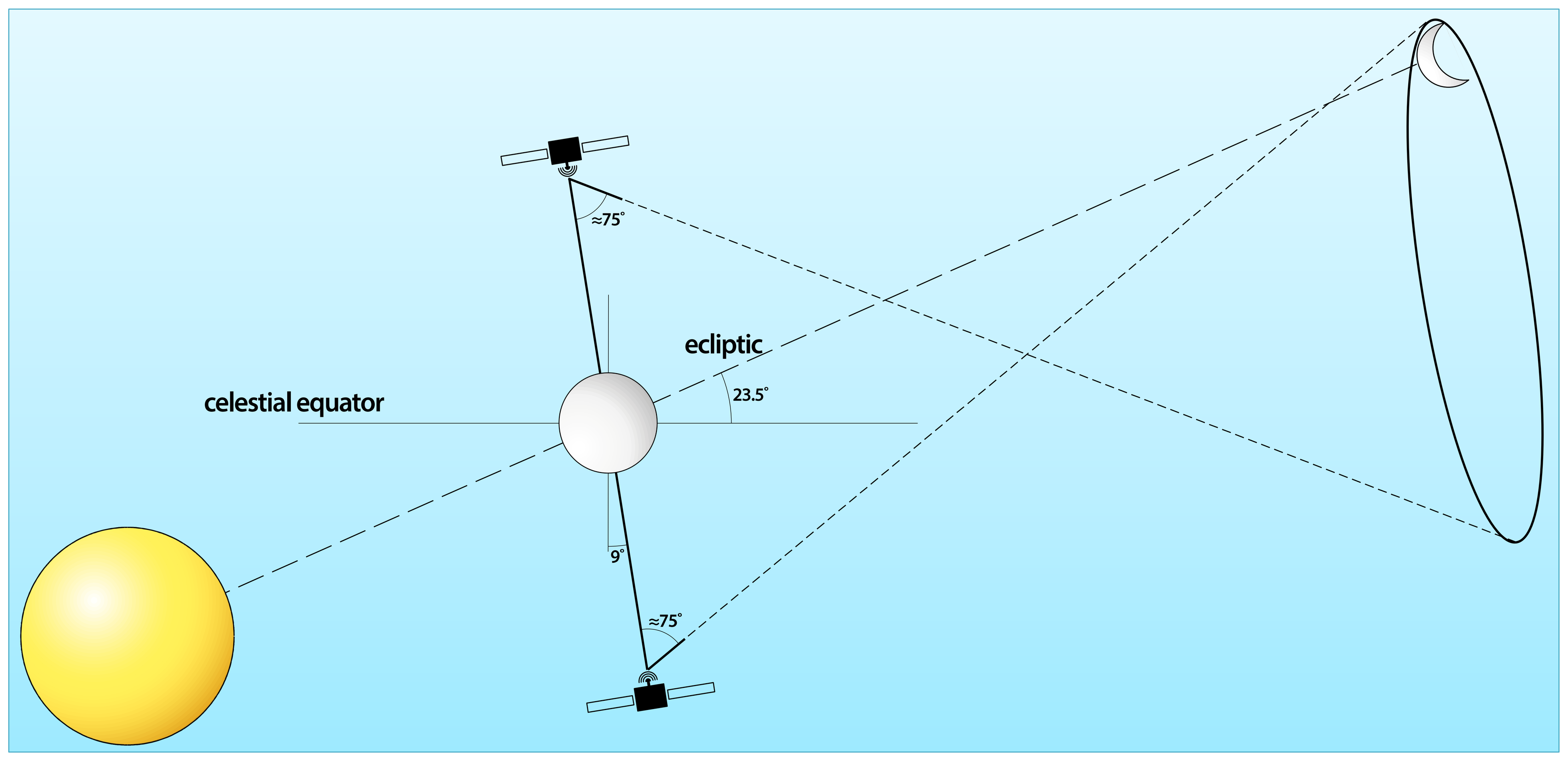
Introduction

Meteorological research satellites on polar orbits observe occasionally the Moon, when it moves through their deep space view. Over the last few decades, a large data set built up, which allows to determine the lunar flux with unprecedented accuracy especially at wavelengths, for which the Earth's atmosphere is opaque. We determined the disk-integrated brightness temperature of the Moon at 19 wavelengths between 4 and 15 μm and at five frequencies between 89 and 190 GHz for phase angles between -80° and +70° with HIRS, AMSU-B, MHS, and ATMS on NOAA and MetOp satellites.

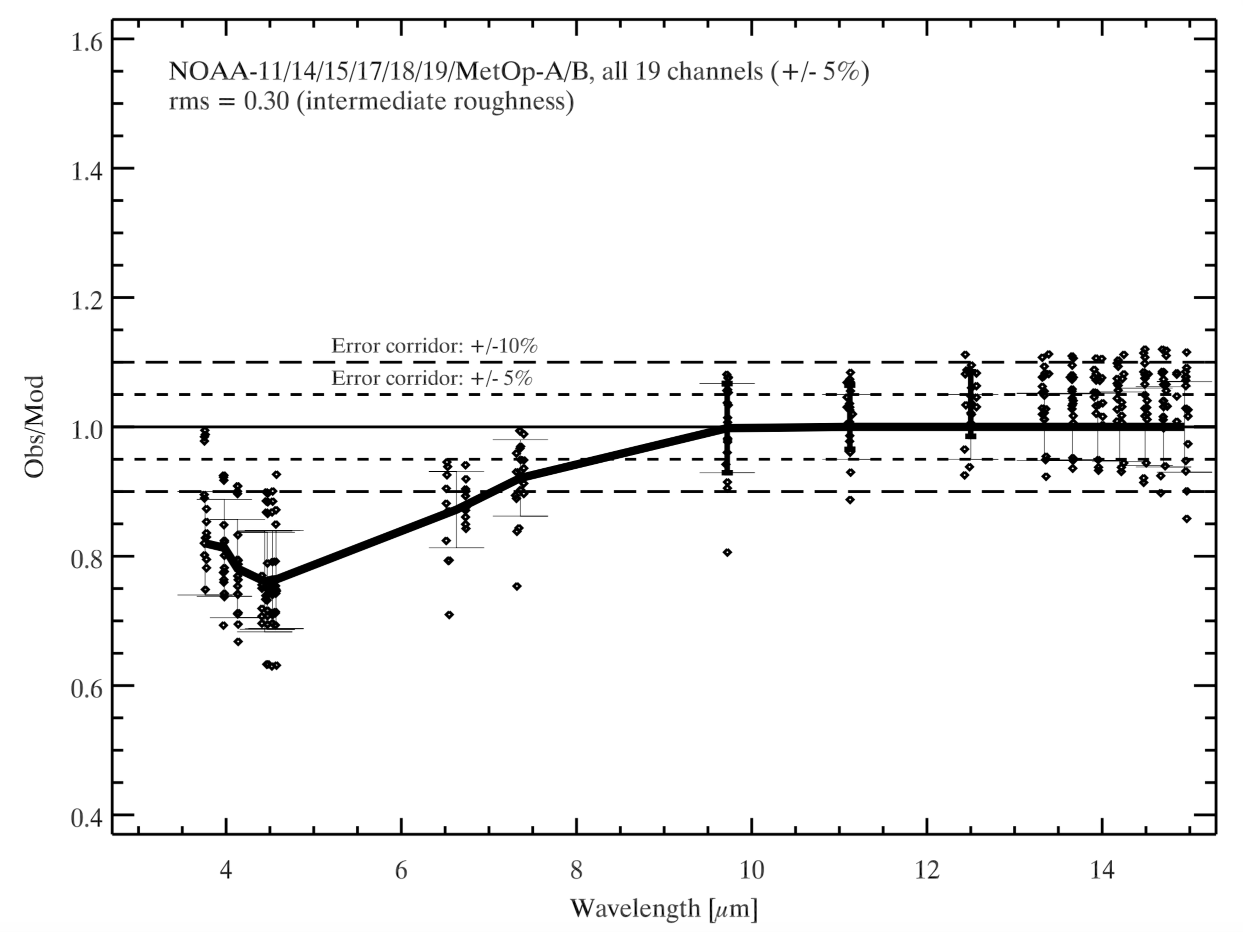
Methodology: Observing the Moon With a Weather Satellite in a Polar Orbit

Most instruments onboard meteorological research satellites use deep space as cold/dark calibration reference. The pointing direction for space is usually within 25° of the orbital axis of the spacecraft. It describes a circle in the sky, close to the celestial equator. The Moon crosses this circle several times per year, and this condition is indicated by a flag in the raw data.



Results: High-resolution InfraRed Sounder (HIRS/2-4)

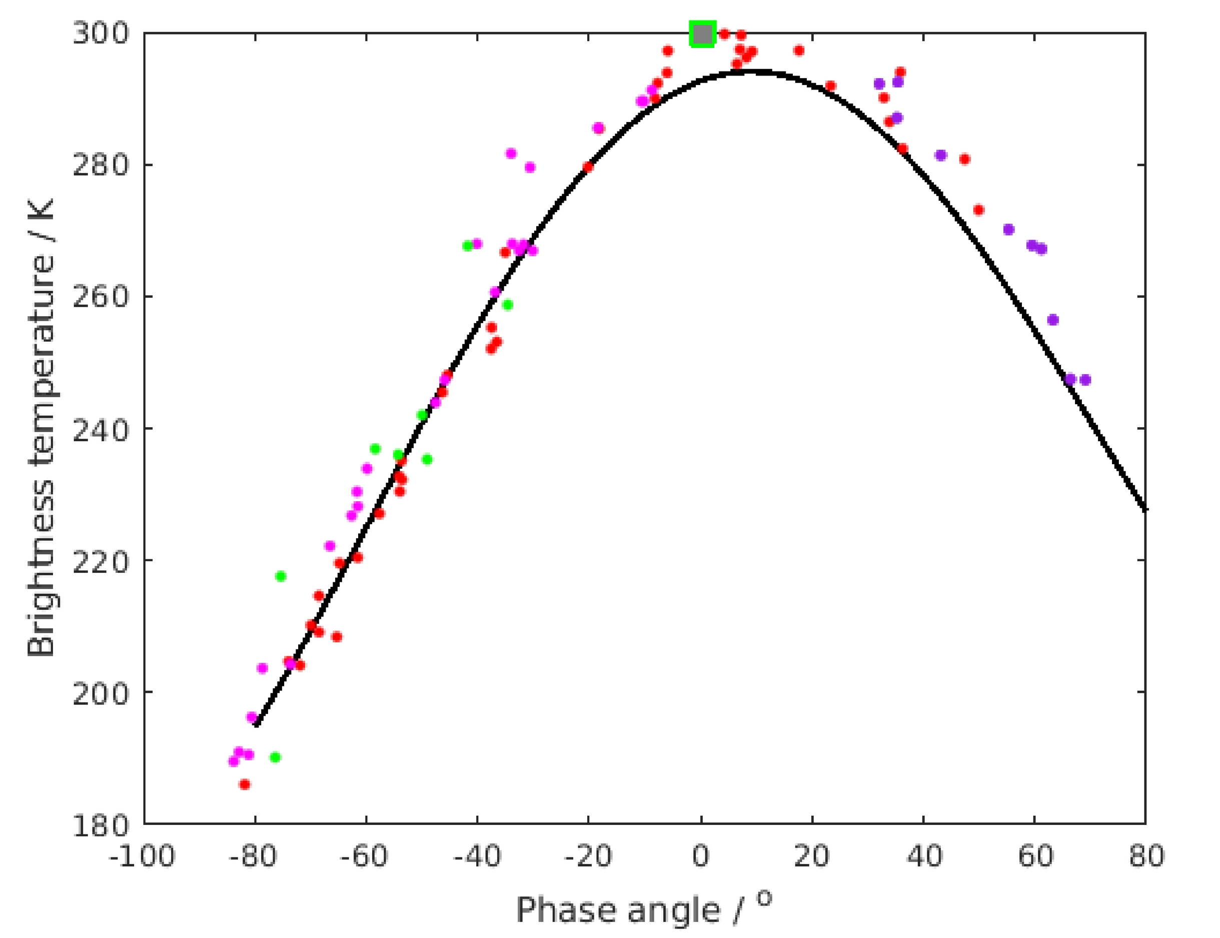
The observations from different λ channels and satellites are very consistent. In general they agree well with a thermo-physical model at λ > 8 μm under the assumption of standard values for albedo, thermal inertia, etc. The model predicts too high flux, however, at shorter λ, suggesting a λ-dependent variation in the directional hemispherical emissivity of the Moon. The scatter in the observation-to-model ratios is related to extreme phase angles.



HIRS measurements of the Moon, obtained during the last three decades and over a wide range of phase angles. The calibrated HIRS fluxes are divided by thermophysical model predictions, using published properties of the Moon's surface and assuming constant values for the geometric V-band albedo (pv = 0.13, Grant, 2008) and the directional hemispherical emissivity (ε = 0.95, Racca, 1995).

Results From MW Sounders

The amplitude of the "light" curve from a Moon intrusion in the deep space view is converted to brightness temperature. Observations from different satellites, represented by symbols of different color in the figure to the right, agree well with a model by Keihm (1984) at 183 GHz. At lower frequencies (not shown) the model gives too low flux densities for the waning Moon, i. e. it has a too small phase lag between full Moon and the maximum brightness temperature of the lunar disk.



Disk-integrated T_b(89 GHz) of the Moon for different phase angles. Green: AMSU-B on NOAA-16, red: MHS on NOAA-18, magenta: MHS on NOAA-19, blue: MHS on MetOp-A, gray square: ATMS on NOAA-20, solid line: model by Keihm (1984).

Discussion

A comparison of our satellite measurements with the predictions from thermo-physical models identifies problematic aspects of the latter. At infrared λ, for example, a λ-dependent directional hemispherical emissivity has to be used to explain the measurements. The high quality of the HIRS data allows to benchmark thermophysical model techniques, which are widely used for the interpretation of infrared measurements of airless bodies. In the microwave range we find that models do not reproduce the difference in flux density between waxing and waning Moon correctly, especially for frequencies below 100 GHz. There is therefore a need to adjust the models of the thermal emission of the lunar disk to the observations with meteorological satellites. These measurements provide a unique set of high-quality data, which spans a wide range of wavelengths and phase angles. They can shed new light on the bulk properties of the lunar surface.

References

Keihm, 1984, Icarus 60(3): 568-589; Matthews, 2008, Applied Optics 47(27): 4981-4993; Racca, 1995, Planetary and Space Science 43(6), 835-842.

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