Professorship of Lunar and Planetary Exploration
TUM School of Engineering and Design
Technical University of Munich

Semester Thesis // Master Thesis

Lunar Surface Temperature Modelling Using LOLA Slope Data and Surface Roughness

theoretical/numerical thesis
Start date: As soon as possible

Topic:

Accurate modelling of lunar surface temperatures is essential for simulating the lunar exosphere. Recent studies indicate that surface slopes and roughness significantly impact local temperature distributions by altering solar incidence angles. The figure below demonstrates existing temperature models, comparing instantaneous temperature snapshots from Diviner measurements (upper left) and a time-average of all Diviner snapshots (upper right) with simplified (lower left) and more complex models (lower right; *Hurley at al.* (2015)), highlighting the limitations in representing the true variability of lunar surface temperatures. Current models typically assign a single temperature to a given global position on the Moon, neglecting the significant influence of regional topography and slope variations. In reality, lunar topography results in a distribution of possible temperatures for each location, primarily due to differences in local solar incidence angles. This project aims to address these limitations by developing an enhanced temperature model that integrates detailed lunar slope and roughness data obtained from the Lunar Orbiter Laser Altimeter (LOLA), providing a more realistic representation of lunar surface thermal environments.

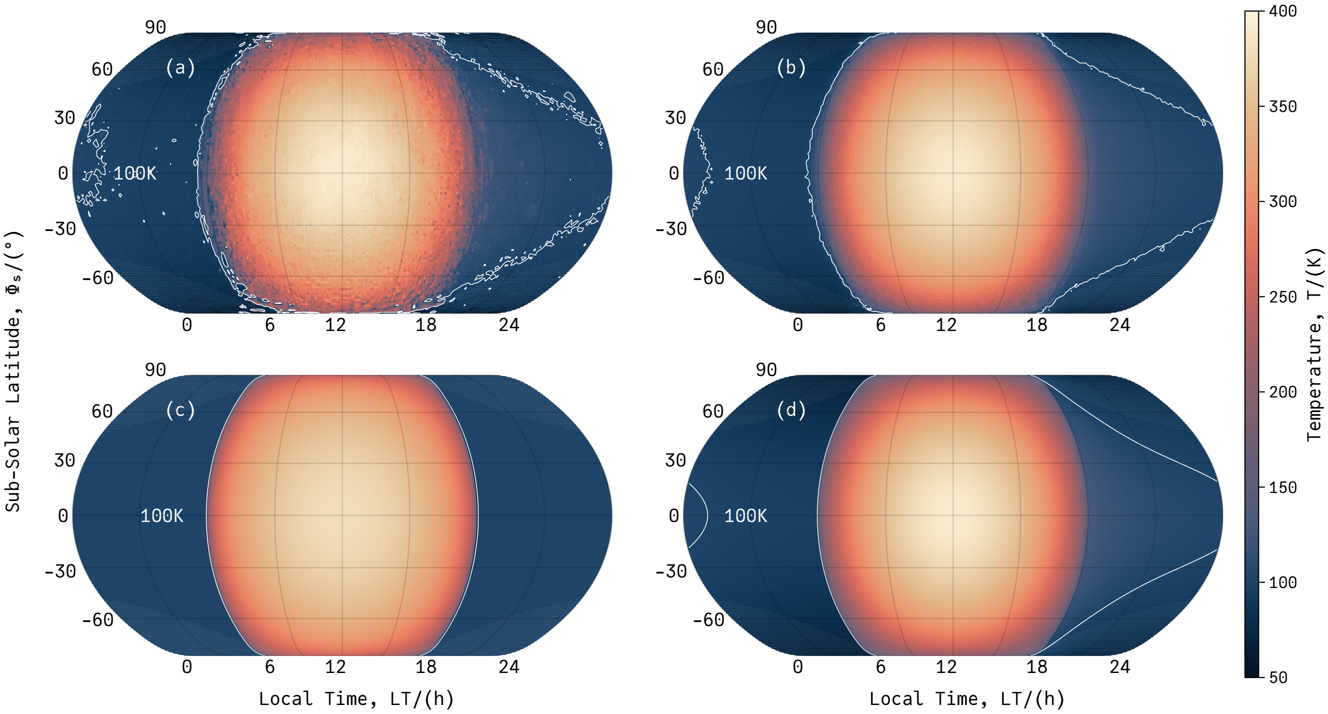

Figure 1: Global, stationary lunar surface temperature maps. The coordinates are given with respect to the sub-solar point at $(\Theta_s, \Phi_s) = (0, 0)$, presented in local time and subsolar latitude. (a) Based on a Diviner measurement snapshot. (b) Based on the average Diviner measurements. (c) Based on the analytic function of *Butler et al. (1997)* and *Crider et al. (2002)*. (d) Based on the analytic function of *Hurley et al. (2015)*.

Tasks:

- **Programming and Software Familiarization (2 weeks):**
  Learn the Julia programming language and familiarize yourself with the following packages:
  - `ExESS.jl`: in-house package for exosphere and surface studies.
  - `Statistics.jl`: for statistical analysis.
  - `BenchmarkTools.jl`: for evaluating computational efficiency.
- **Literature Review on Lunar Temperature Models (4 weeks):**
  Study the lunar thermal environment and examine existing models, focusing on Diviner mission data and the methodologies of *Hurley et al. (2015)*, *Prem et al. (2018)*, and *Bürger et al. (2024)*.
- **Analysis of LOLA Data and Slope Distributions (2 weeks):**
  Understand LOLA data products, particularly lunar surface slope distributions, and relate them to solar incidence angles to evaluate their effect on surface temperatures.
- **Development of a Slope-Informed Analytical Model (6 weeks):**
  Create a statistical model for lunar surface temperature distribution based on LOLA-derived slopes. Ensure compatibility with established statistical means (e.g., *Hurley et al.* (2015)) and explicitly include local slope-dependent solar incidence angles.
- **Model Validation and Benchmarking (4 weeks):**
  Analyze the physical accuracy of the developed temperature model, including an examination of maximum and minimum temperature extremes. Additionally, perform extensive numerical benchmarking to assess computational efficiency and numerical stability.
- **Documentation and Reporting (4 weeks):**
  Produce detailed scientific documentation summarizing methodologies, model specifications, validation procedures, benchmarking results, and implications for lunar exosphere simulations.

This project will deliver an improved analytical model of lunar surface temperatures, explicitly incorporating slope and surface roughness effects. It will provide critical insights into temperature extremes and evaluate their physical plausibility. Additionally, the project will assess the computational efficiency and numerical stability of the developed model, culminating in comprehensive documentation that will serve as a foundational reference for future lunar exosphere simulations.

Requirements:

- Basic knowledge of planetary sciences, preferably lunar surface processes.
- Interest in numerical modelling and data analysis.
- Previous programming experience; willingness and ability to learn Julia.
- Familiarity with statistics and benchmarking methodologies (advantageous but not essential).
- Motivation to independently explore scientific literature and datasets.
- Good command of the English language

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