



# **THE MYSTERY OF LUNAR WATER**

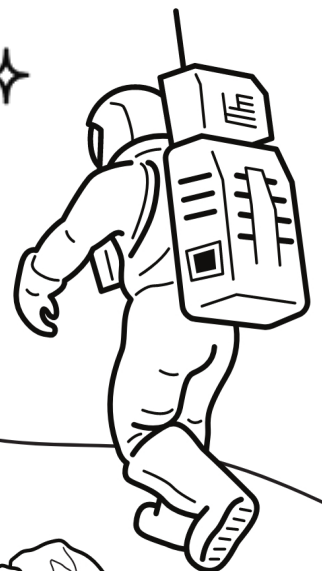
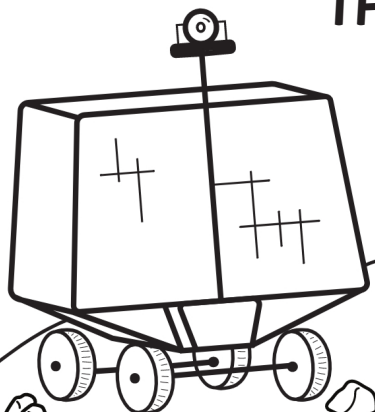


## **HELP SCIENTISTS UNCOVER WATER ICE ON THE MOON**



### **PART 1**

**THIS ACTIVITY IS DESIGNED FOR  
AGES 9 AND UP.**





## STUDENT GUIDE

### INTRODUCTION



We want to send astronauts back to the Moon to areas near the south pole that contain frozen water (referred to as water ice in this guide). But first, you need to discover where water ice is the most plentiful. To do this, you need to compare data from many of the instruments on the Lunar Reconnaissance Orbiter (LRO) satellite to find areas that show water ice in all the datasets. Scientists are doing similar studies right now to answer the same question! Help scientists locate where water ice exists on the surface in the form of surface frost. Locations of surface frost will help scientists search for water ice and other frozen resources buried beneath the surface.



### BACKGROUND INFORMATION



There are regions near the Moon's north and south poles that never receive sunlight (**Figure 1**). Such regions, known as permanently shadowed regions (PSRs), can maintain very cold temperatures (down to  $-415^{\circ}\text{F}$  or  $-248^{\circ}\text{C}$ !). At these cold temperatures, ice can be made from many frozen substances, including water, carbon dioxide ( $\text{CO}_2$ ), sulfur, and hydrogen.



### INSTRUCTIONS



#### Supplies:

- **Colored pencils, markers, or other writing tools.**
- **Printouts of the Coloring Page (Hillshade) to color on for each student**
- **Digital or Printouts of the maps**

The goal of this activity is to find at least one location where astronauts should go to search for water ice. To do this, compare each of the provided maps to find locations where all four maps (WAC Summer Mosaic with PSRs, Diviner Maximum Temperature, LOLA 1064 nm albedo, and LAMP UV off/on-band ratio albedo) show results consistent with surface water ice.

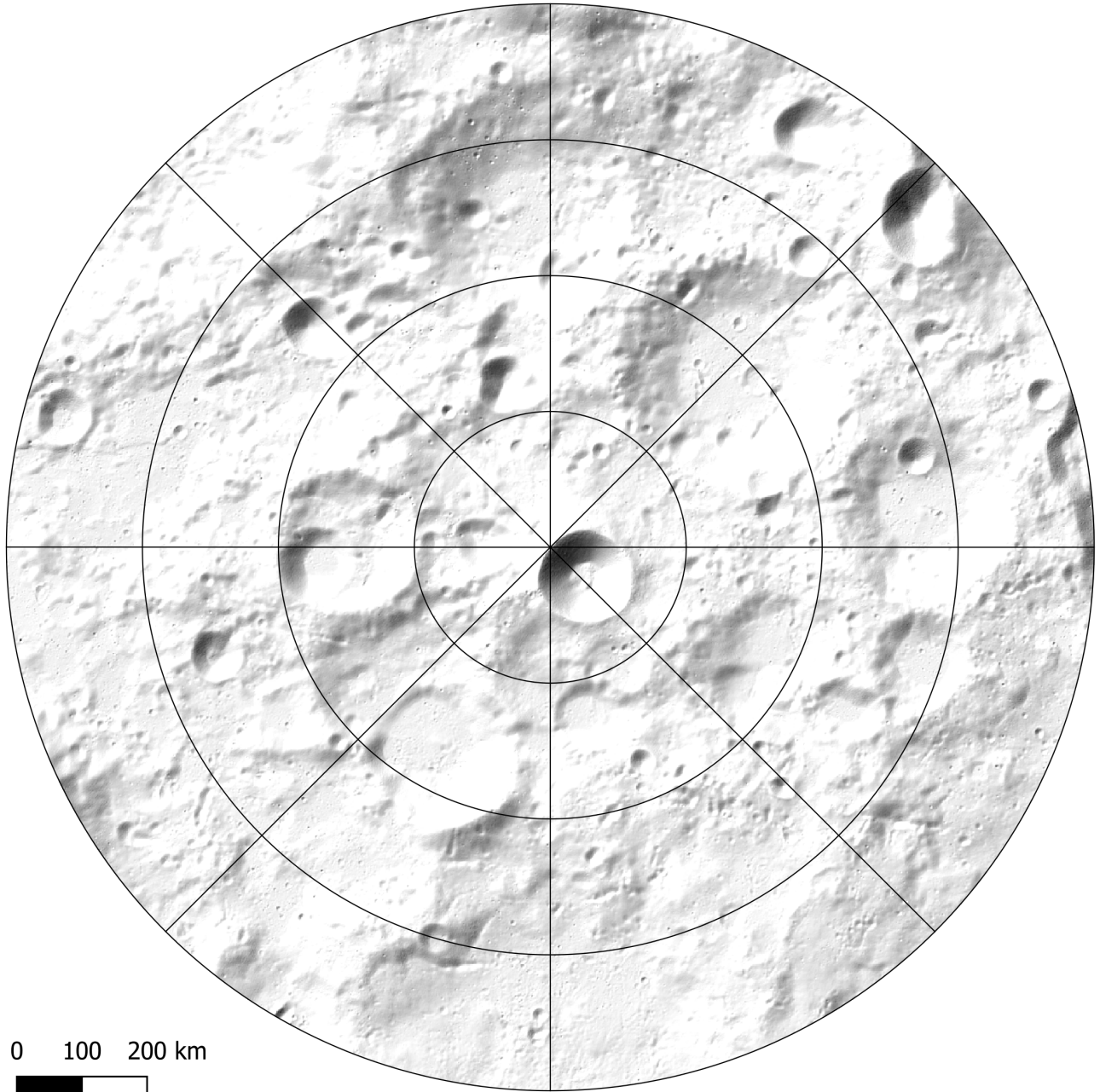
Each map has a different legend, but results that are consistent with surface water ice are indicated by the dark blue color in each map. The PSRs are also outlined in dark blue.

There are several locations that might contain water ice, so to make the activity more challenging, identify multiple locations where scientists suspect water ice may be found. Colored pencils can be used to shade in the area(s) most likely to have water ice on the Coloring Page.

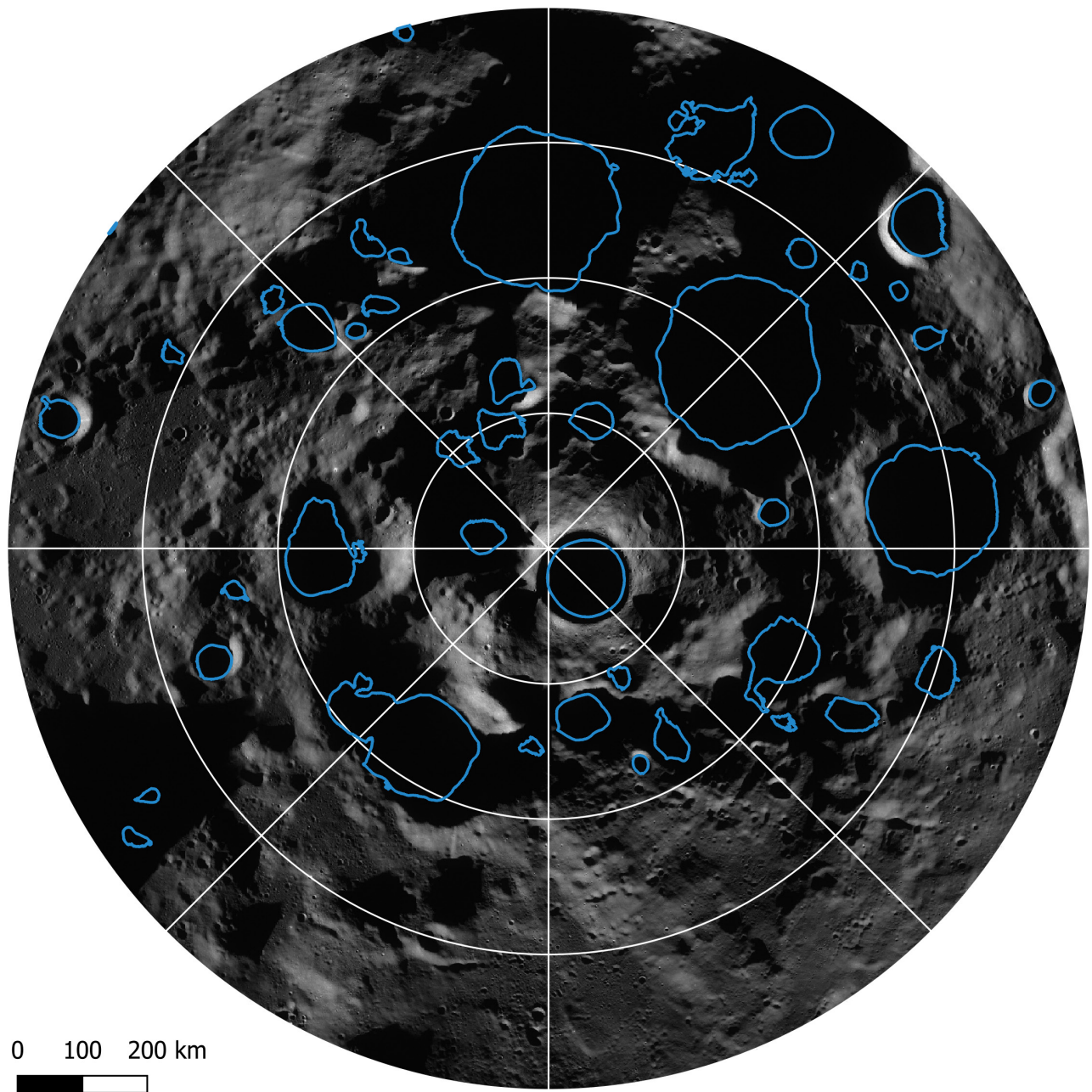
answer sheet is provided in the instructor packet so you can check your work.



# COLORING PAGE - HILLSHADE

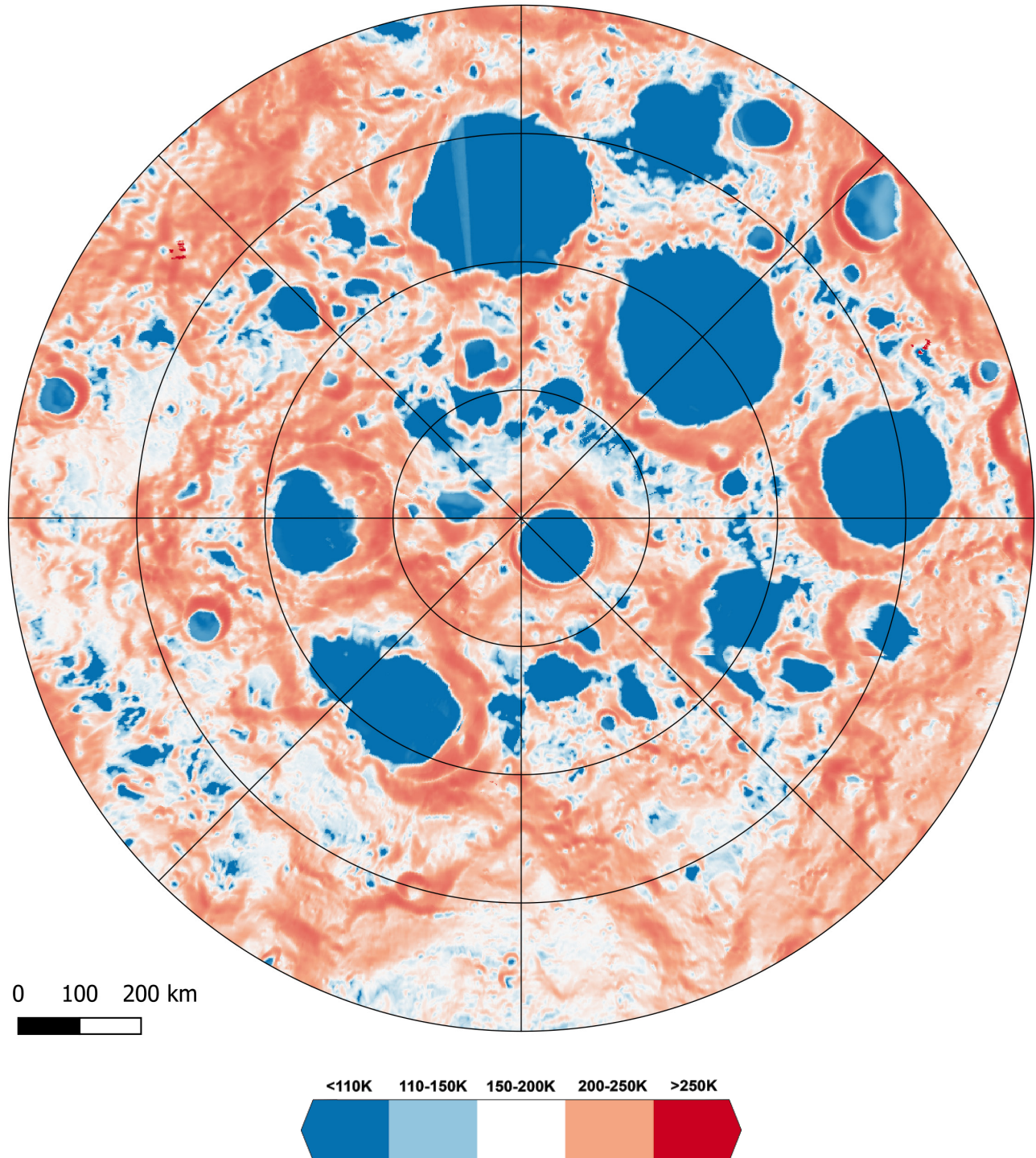


# LROC WAC SUMMER MOSAIC WITH PSRs



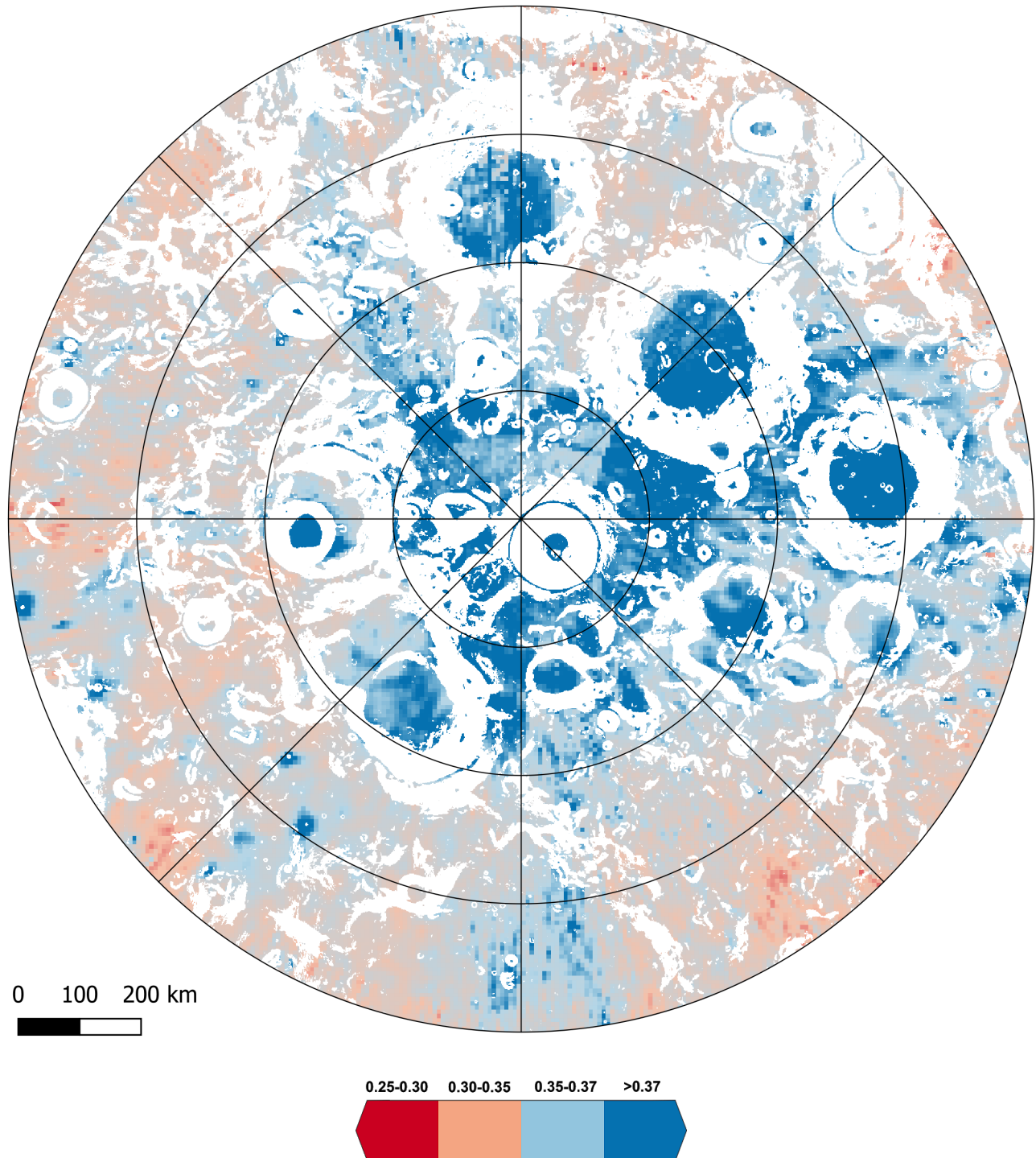
The WAC south pole summer mosaic is composed of images from the Lunar Reconnaissance Orbiter Camera (LROC) Wide Angle Camera (WAC) taken during the summer (from 21 September 2010 to 23 October 2010). The summer is when the south pole receives the maximum amount of sunlight, although not enough to light up the insides of most craters. Outlined in **dark blue** are the permanently shadowed regions. Because these areas never receive direct sunlight, it is possible that they contain water in the form of ice.

# DIVINER MAXIMUM TEMPERATURE



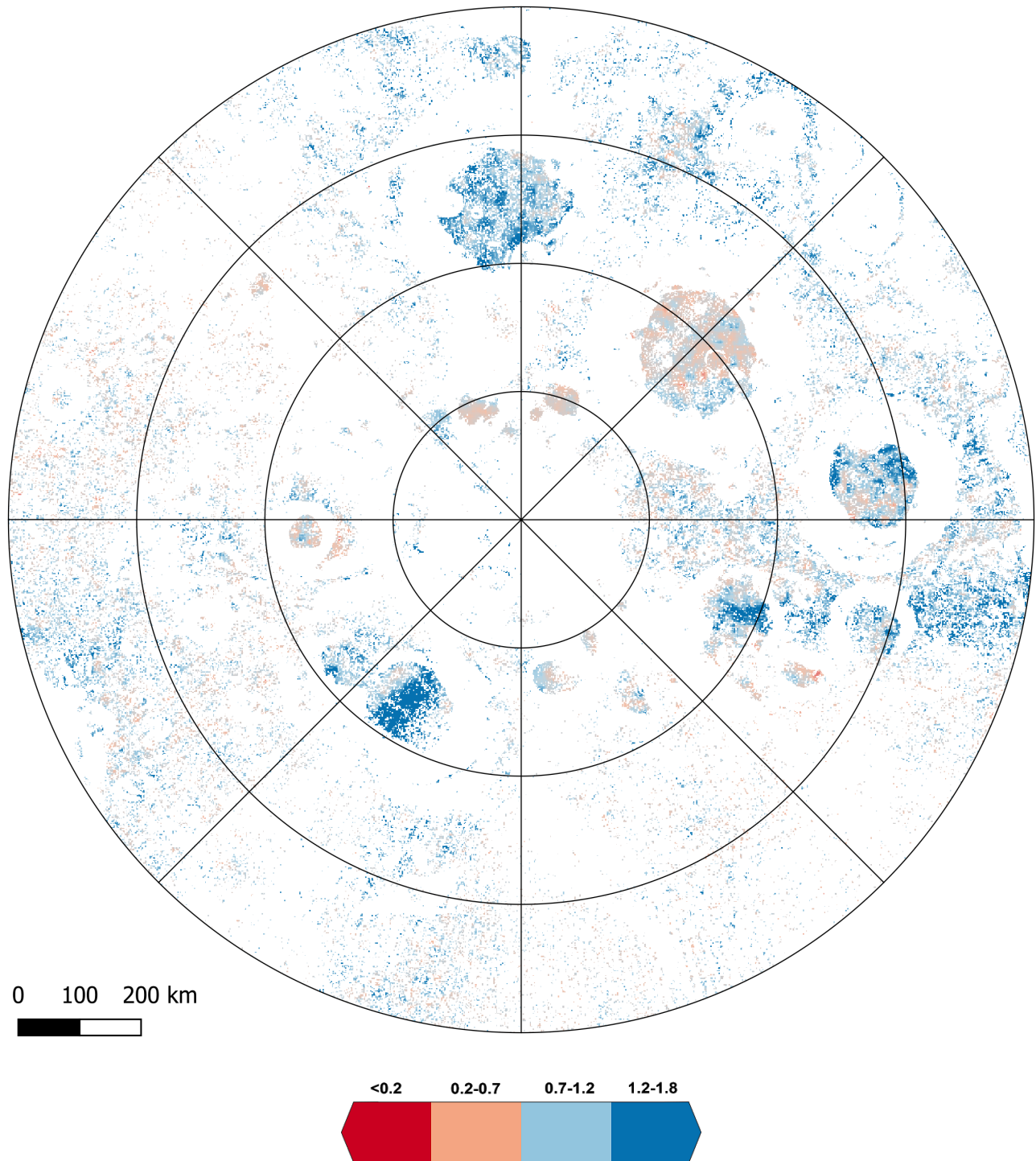
The maximum temperature in degrees Kelvin (K) over an entire year was measured by the Diviner Lunar Radiometer Experiment (Diviner, for short). **Values < 110 K (-262° F; dark blue)** are cold enough to trap water ice.

# LOLA 1064 NM ALBEDO MAP



This albedo map was created by the Lunar Orbiter Laser Altimeter (LOLA) instrument team. Albedo is a measure of how much a material reflects light. So, a surface that appears brighter has a higher albedo than one that appears darker. One material that is reflective and can appear bright is water ice in the form of surface frost, so this map can help us tell where surface water ice might be located. **Values of >0.37 (dark blue)** are bright enough to indicate surface water ice. Another kind of surface that appears bright is the walls of steep craters. So to help with interpretation, steep crater walls have been removed from this map (**white**).

# LAMP UV OFF ON-BAND RATIO UV ALBEDO MAP



This map of the reflectance (or albedo) in the ultraviolet (UV) spectrum was measured by the LAMP instrument. LAMP's Off-band is a near-perfect reflector of water ice, so the LAMP team took the ratio of the 'On-Band' and 'Off-Band' maps to more easily detect water ice. **Values >1.2 (dark blue)** are consistent with surface water ice.

## GLOSSARY

**Albedo** - Albedo is a measure of how much a material reflects light. A surface that appears brighter has a higher albedo than one that appears darker.

**Commercial spaceflight organizations** - Nongovernmental companies that provide space goods, services, or activities. Some American commercial spaceflight organizations that work with NASA include Boeing and SpaceX.

**Drive system** - A system that controls speed, rotation, and direction of a motor in a machine.

**Earth line-of-sight communication** - Communications between Earth and rover are made possible because Earth is in constant view. Only the nearside of the Moon is in constant line-of-site.

**Electromagnetic spectrum** - Made up of waves (wavelengths) that travel through space at the speed of light. Waves differ in frequency (long vs. short waves).

**Elements** - Chemical elements that are matter in the universe. Elements are atoms with a specific number of protons.

**Engineering** - Designing and building new products, machines, or systems using chemistry, physics, and math to solve problems. Different kinds of engineering are often used together when designing something. Building a rover for example uses a combination of electrical engineering (designing how the machine is powered), mechanical engineering (the design, construction, and use of the machine), and materials engineering (designing and building new materials).

**Farside** - The face of the Moon that faces away from Earth. Sometimes inaccurately called the “dark side”. During a new moon on Earth, the farside is illuminated by the Sun; when we see a full moon, the farside is dark.

**Hillshade** - Hillshading is a process of adding light and dark shading to a topographical map to represent sunlight and shadow, allowing us to see surface features such as mountains and craters.

**Kelvin** - K, the abbreviation for Kelvin, is the base unit of temperature in the International System of Units. Compared to Celsius and Fahrenheit, which are most useful for taking everyday temperatures (water freezes at 0°C, 32°F), Kelvin is useful for measuring much colder material (water freezes at 273.15 K).

**Map Legend** - A key or visual explanation for how to read colors and symbols on a map.

**Nearside** - The face of the Moon that we see from Earth is called the nearside.

**Pixel scale** - A pixel (short for picture element) is one of many small squares that make up a picture. The number of small squares in a picture controls the resolution of a picture. In a satellite image, the amount of ground covered by one pixel is referred to as the pixel scale.

**Power** - In physics and science, power refers to the rate, or how fast, energy is used. Power comes from “work”, or the transfer of heat or energy to an object.

**Reflectance** - Measure of how light or dark a surface appears. See “Albedo”.

**Surface frost** - On Earth, frost is a thin layer of ice crystals formed when water vapor (a gas) comes into contact with a surface, thus changing the water vapor into ice (a solid). On the Moon, surface frost is not only water; other chemicals such as sulfur, ammonia (NH<sub>3</sub>) and methane (CH<sub>4</sub>) are thought to exist as well.

**Suspension system** - How the wheels are connected to a rover; provides control of how the rover interacts with the terrain.

**Tidal Locking** - The Moon completes a full rotation about its axis in about the same time it takes to orbit the Earth, resulting in the same side of the Moon always facing towards Earth.

**Traverse** - Planned path that rover will travel during a mission.

**Vacuum** - The vacuum of space is empty (contains almost no matter) and cold; a vacuum is a space where pressure is so low that any particles in the space do not affect processes that occur.

**Water ice** - Frozen materials such as water can be trapped in the permanently shadowed regions on the Moon because of their cold temperatures. There is no liquid water on the Moon.

**Watts** - Unit used to measure power, or the rate at which energy is used.