Simulating a liquid water cycle in early Mars climate scenarios

National Aeronautics and Space Administration

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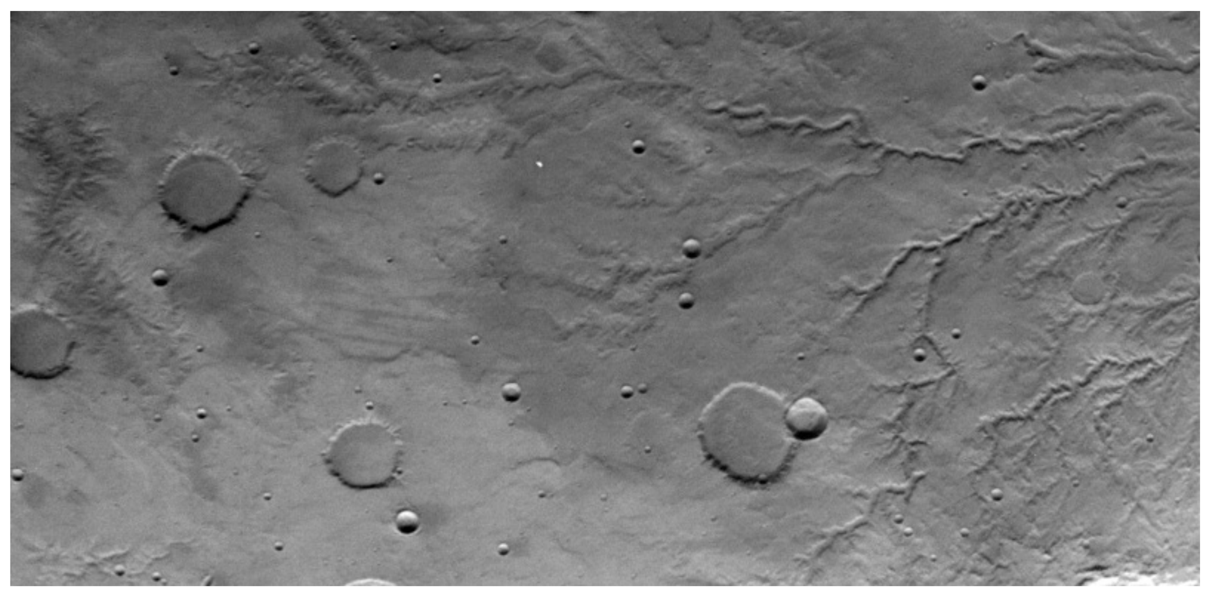
Science Goal

Explore Mars climate scenarios that could have facilitated river valley network formation 3.5-3.75 billion years ago.

Summer Project Objective

Develop and incorporate a liquid water cycle into the NASA Ames Research Center (ARC) Mars Global Climate Model (GCM).

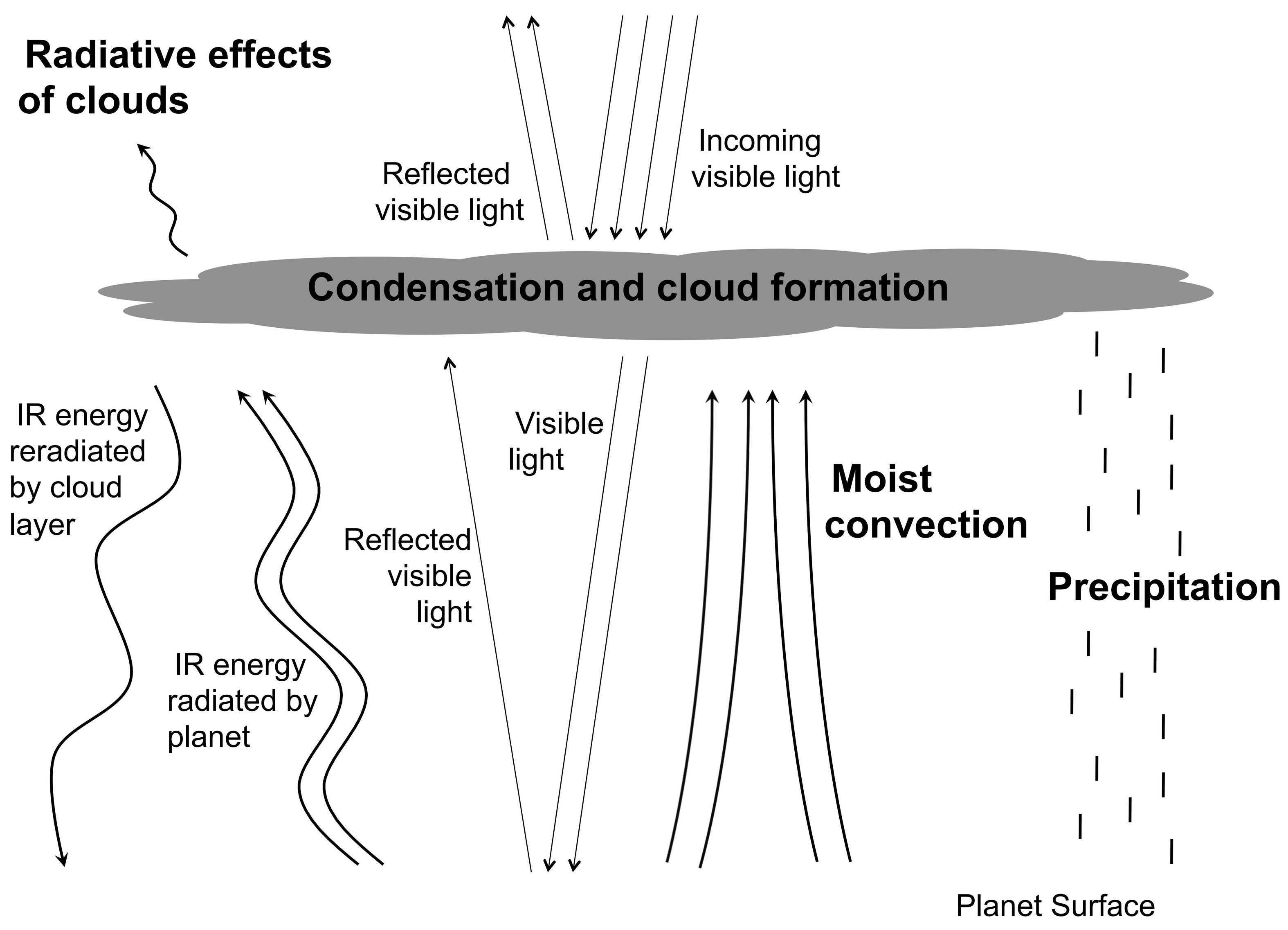


Parana Valles, a martian valley network located ~ 23° S, 10° W. Image 250 km across. Photo credit: NASA (Viking Orbiter image F084A47).

Background

- Geological evidence suggests liquid water was stable on Mars' surface 3.5 - 3.75 Gya [1,2,3,4].
- Most martian river valley networks likely formed from precipitation and runoff [4] over ~10^2 - 10^4 years [5].
- Modeling attempts to reproduce warm, wet conditions have been largely unsuccessful, mainly because the Sun's luminosity 3.8 Gya was 75% of current value [6,7,8,9].
- The ARC Mars GCM's hydrological cycle currently only accounts for water vapor and ice given current Mars' low surface pressures and temperatures.
- Compared with water ice clouds, liquid water clouds form at warmer temperatures, hold more water, contain droplets undergoing coagulation, and are often associated with moist convection.
- Modeling a liquid hydrological cycle is necessary to investigate the nature of the early martian climate.

Components of the liquid water cycle



Condensation and cloud formation:
Water vapor condenses to form clouds when the atmosphere is supersaturated. We use the scheme described in [10] and [11] assuming a constant particle density of cloud condensation nuclei (CCN). Total mass of water condensed and CCN are used to determine cloud particle size.

Precipitation:
If the water content within a cloud exceeds a threshold of 0.001 kg of condensed cloud water per kg of air [10, 12], excess cloud water falls to the surface as precipitation.

Moist convection:
Moist air is more susceptible to becoming convectively unstable than dry air. This can result in the transport of warm, wet air up to higher altitudes, causing condensation and precipitation [13]. We implement the Manabe scheme for moist convection described in [14] and [15]. When relative humidity exceeds 100% and the temperature gradient in the atmosphere exceeds the moist adiabatic lapse rate, we relax the temperature profile back to a moist adiabat while condensing water vapor until relative humidity returns to 100%.

Radiative effects of clouds:
The optical properties of liquid water clouds affect the total energy balance of the atmosphere. We update the radiation code to account for Mie scattering in liquid water clouds.

Expected Results

We incorporate new physics into the ARC Mars GCM to simulate a liquid hydrological cycle. This liquid water cycle includes a moist convection scheme, condensation and cloud formation, precipitation, and the radiative effects of liquid water clouds.

Future Work

Utilize the upgraded version of the model developed this summer to explore impacts from comets and asteroids as a potential heating mechanism for early Mars.

References

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