Cloudy

with a chance of high uncertainty

Preliminary results on the addition of self consistant clouds to a coupled climate and photochemistry model

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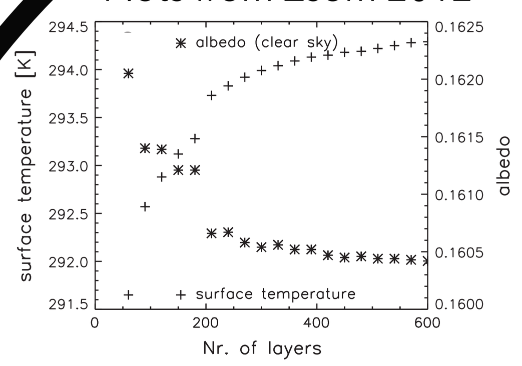
Abstract

Here on Earth the shade of a cloud can provide momentary relief on a brutally hot summer day but for life on exoplanets clouds can mean the difference between life and death. In this work we explore the role water clouds play on the habitability of recently discovered exoplanets on the inner edge of the classically defined habitable zone and how the presence of clouds would influence the detectability of potential biosignatures. Using a coupled climate and photochemistry model we first simulate cloud evolution in these environments to determine surface conditions. Through the modeling process we also obtain the photochemically stable profiles of various molecules that may be present in the atmosphere. These profiles can be used to generate spectra that mimic future observations using reflected light or transmission.

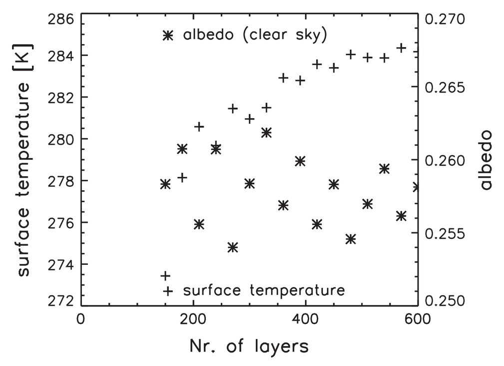
Clouds can hinder our ability to identify the atmospheric composition of exoplanets and also play a big roll in the energy balance of the climate. Our work will determine the extent of these effects, provide constraints on the range of habitable environments one would expect to find, and point to which ones would most likely be detectable in the near future. This type of study is very useful in the current stages of exoplanet characterization as the difficulty of these measurements makes fully thought out candidate prioritization an essential component of finding life sooner rather than later.

Cloud Model

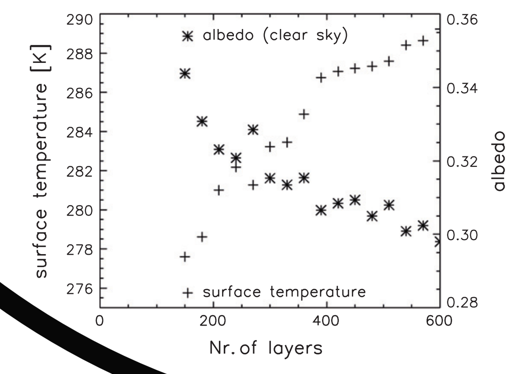
Plots from Zsom 2012



No Clouds



Simple Clouds



Our Clouds

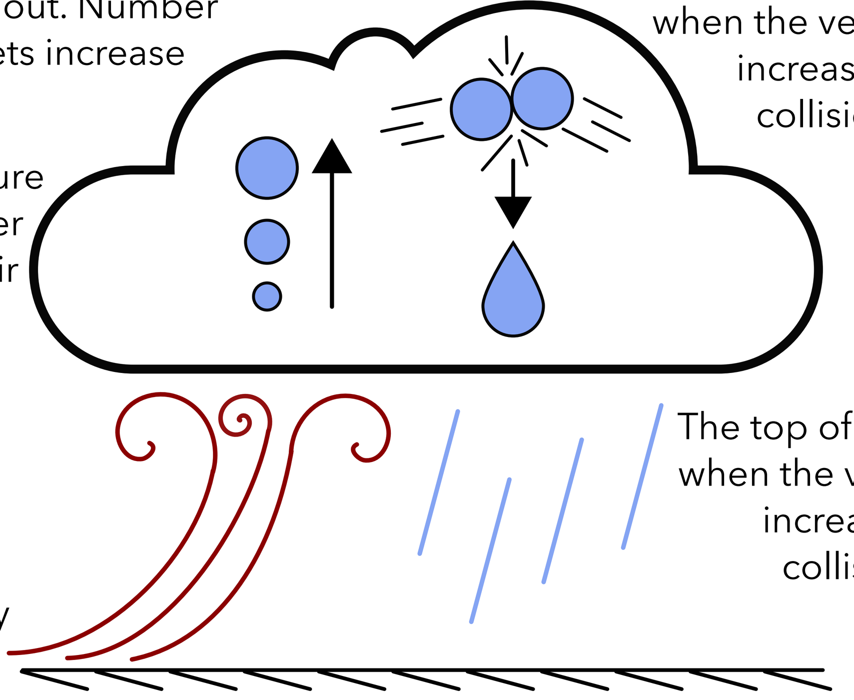
The 1D cloud model we have implemented self consistently calculates the height and density of the liquid and ice cloud layers based on Earth observations. The cloud model convergence tests shown to the left tell us that the model has greater accuracy than simpler models that use parameterized clouds.

How our clouds work

As warm air rises and cools more vapor condenses out. Number and size of droplets increase with height.

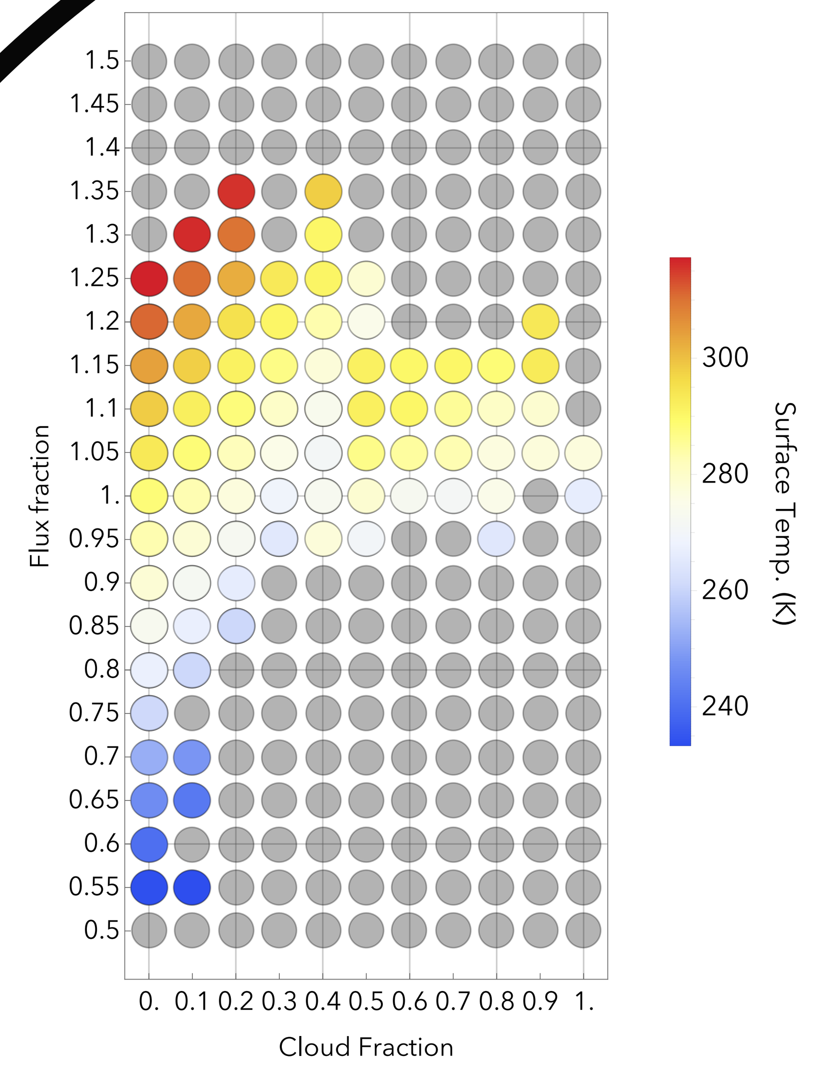
The top of the cloud is calculated when the velocity between drops increases to the point where collisions become efficient.

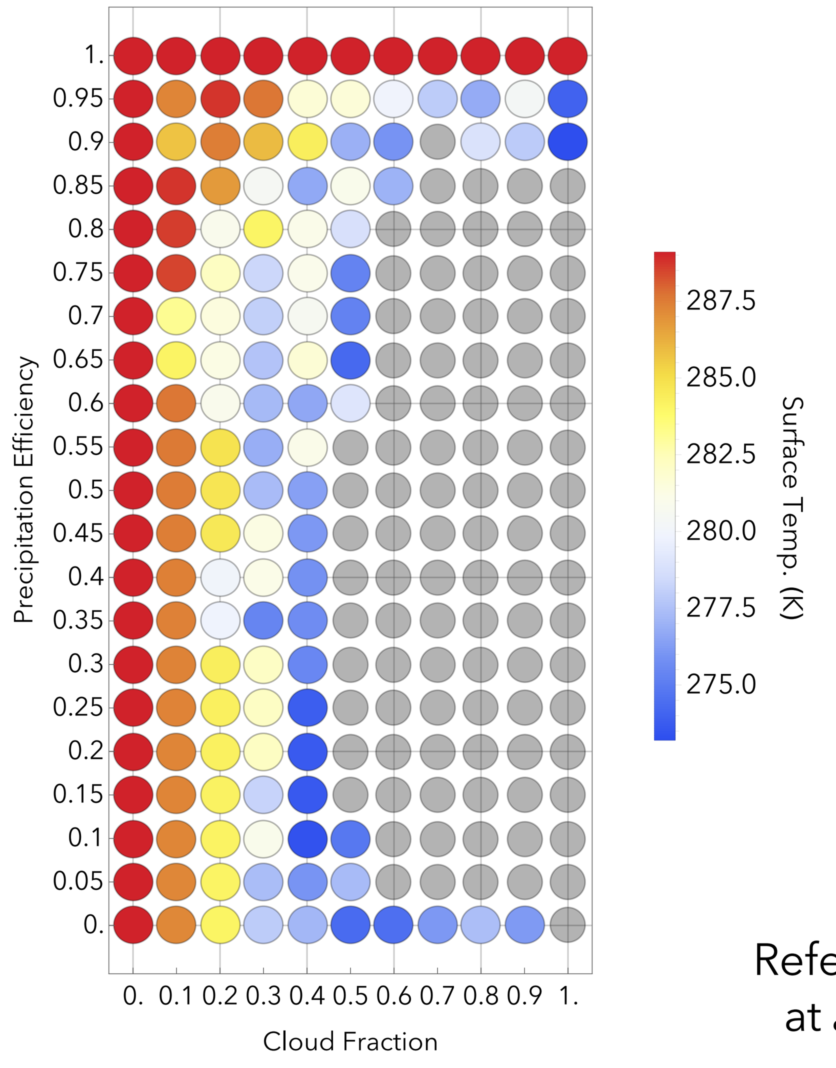
For a given temperature and pressure there is a maximum amount of water that can be held as a vapor in the air before it starts to condense. The bottom of the cloud is determined when the humidity matches this saturation level.



The top of the cloud is calculated when the velocity between drops increases to the point where collisions become efficient.

Cloud formation depends on pressure, temperature, relative humidity, and number density of aerosols. They usually form with an updraft of warm humid air.



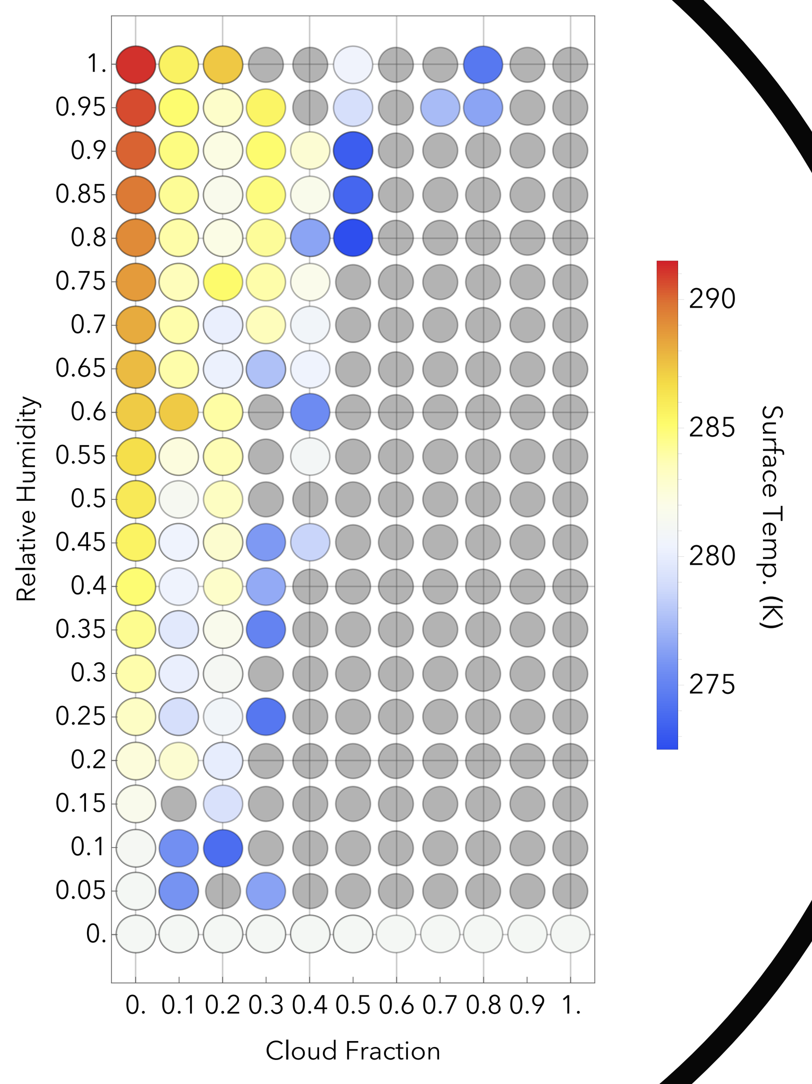


Findings

With a model that allows for the manipulation of over 40 free parameters we chose to start with effective flux, relative humidity, and precipitation efficiency. The other parameters were set to match Earth values as closely as possible to achieve a balance between accuracy and speed. To indirectly assess habitability we plot the surface temperature as a function of the changing parameters. Each dot represents a single run of our model with the colored dots showing a converged surface temperature and the gray dots showing where our model did not find a stable solution.

Conclusions

It is clear that our models can be used to explore trends in how clouds interact with the other parameters in the simulation but there are many areas of uncertainty that need to be addressed. This points out the larger issue of how to accurately generate self consistent clouds in a 1D climate and photochemistry model. These trial runs have shown that clouds can have profound effects on the habitability and stability of exoplanets modeled with our code.



References can be found online at *astro.cornell.edu/~jmadden*