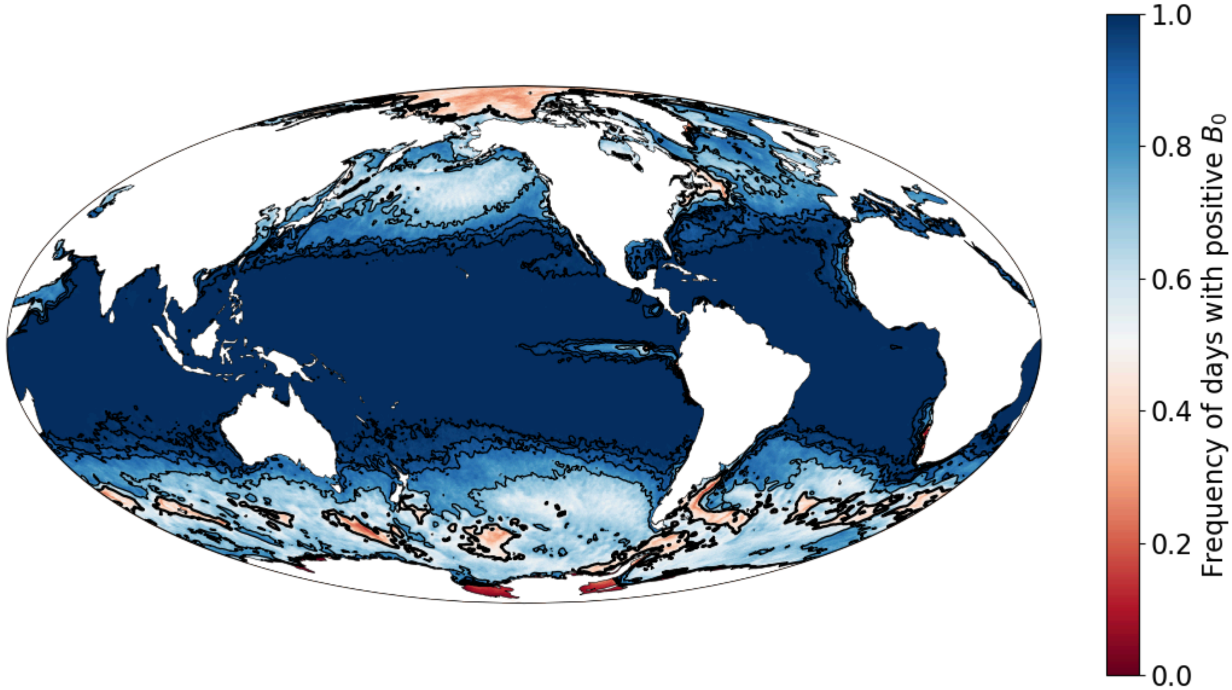
Reviewer 2

The authors present a novel and original approach to estimating near-surface humidity from cloud-base height information using atmospheric thermodynamics. The manuscript is clearly written, and the uncertainties in the approach are well addressed. I have a few minor suggestions for improvement.

Suggestions.

Figure 1: This is a nice figure. As a suggestion, would it be possible to more clearly distinguish between regions that have a frequency of days with positive B0 < 0.5, for example by using a color table with blue and red colors for values <0.5 and >0.5, respectively?

Thank you. We have implemented this suggestion to better show regions with frequency <0.5.



Theory section 4: There is some widely used earlier work that relate near-surface thermodynamic properties to the LCL. Could you briefly compare your analytical relations with those from, for example, Romps (2017) and Lawrence (2005)?

Response: Thank you. We have added a paragraph in Section 3 explicitly comparing our analytical relations with those of Romps (2017) and Lawrence (2005), clarifying that our relative-humidity lapse rate is the same linearized limit underpinning both earlier LCL formulae, but that our framework inverts the relationship as a retrieval from observed cloud base height rather than a forward calculation from known surface conditions.

“Our analytical framework is closely related to earlier work connecting near-surface thermodynamic properties to the lifting condensation level. \citet{lawrence2005relationship} provided a simple linear approximation relating the dewpoint depression to relative humidity, showing that $\RH \approx 1 - (T - T_\rd)/A$ with $A \approx \SI{4.3}{\kelvin}$ near typical surface conditions; inverting this for a well-mixed subcloud layer yields an LCL height proportional to the dewpoint depression, consistent with the classical \SI{125}{\meter\per\kelvin} rule. \citet{Romps2017} derived an exact, implicit expression for the LCL temperature and pressure by conserving entropy and total water along a dry adiabat, obtaining an analytical result valid over a wide range of conditions. Our approach differs in emphasis, in that rather than computing the LCL from surface (T, q), we invert the relationship ---given a remotely sensed cloud base height h, we recover \RHa and hence $q_\ra$.”

Eq. (3). It would be helpful if you could give some more elaboration explanation about how to arrive at Eq. (3)?

Thank you. We have added an Appendix A deriving Eq. (3) step by step, as requested.

\appendix

\section{Derivation of the adiabatic relative-humidity lapse rate}

Starting from the definition of relative humidity,

\begin{equation}

\RH = \frac{e}{e_*(T)},

\end{equation}

we take the vertical derivative of its logarithm,

\begin{equation}

\frac{\rd}{\rd z} \ln \RH

= \frac{1}{e} \frac{\rd e}{\rd z}

- \frac{1}{e_*} \frac{\rd e_*}{\rd z}.

\label{eq:dlnRH}

\end{equation}

Using the Clausius--Clapeyron relation,

\begin{equation}

\frac{\rd \ln e_*}{\rd T}

= \frac{\ell_\rv}{R_\rv T^2},

\end{equation}

the second term becomes

\begin{equation}

\frac{1}{e_*} \frac{\rd e_*}{\rd z}

= \frac{\ell_\rv}{R_\rv T^2} \frac{\rd T}{\rd z}.

\end{equation}

For the vapor pressure term, we write

\begin{equation}

e = q \frac{R_\rv}{R} P,

\end{equation}

where $R = (1-q)R_\rd + qR_\rv$ is the gas constant of moist air.

Taking the logarithmic derivative,

\begin{equation}

\frac{1}{e} \frac{\rd e}{\rd z}

= \frac{1}{q} \frac{\rd q}{\rd z}

+ \frac{1}{P} \frac{\rd P}{\rd z}

- \frac{R_\rv - R_\rd}{R} \frac{\rd q}{\rd z}.

\end{equation}

Using hydrostatic balance,

\begin{equation}

\frac{\rd P}{\rd z}

= -\rho g

= -\frac{P}{R T} g,

\end{equation}

so that

\begin{equation}

\frac{1}{P} \frac{\rd P}{\rd z}

= -\frac{g}{R T}.

\end{equation}

Substituting into Eq.~\eqref{eq:dlnRH} yields the general expression

\begin{equation}

\frac{1}{\RH} \frac{\rd \RH}{\rd z}

=

\left[

\left(\frac{1}{q} - \frac{R_\rv - R_\rd}{R}\right)

\frac{\rd q}{\rd z}

- \frac{g}{R T}

- \frac{\ell_\rv}{R_\rv T^2}

\frac{\rd T}{\rd z}

\right].

\label{eq:general_RH_lapse}

\end{equation}

In a well-mixed, unsaturated subcloud layer,

\[

\frac{\rd q}{\rd z} \approx 0,

\qquad

\frac{\rd T}{\rd z} \approx -\frac{g}{c_p},

\]

so Eq.~\eqref{eq:general_RH_lapse} reduces to

\begin{equation}

\frac{1}{\RH} \frac{\rd \RH}{\rd z}

=

\frac{g}{T}

\left(

\frac{\ell_\rv}{c_p R_\rv T}

- \frac{1}{R}

\right),

\end{equation}

which corresponds to Eq.~\ref{eq:adiabatic} in the main text.

line 129: maybe you could already mention the effect of precipitation at this point (elaborated later in the manuscript)?

We added a phrase at the end of this sentence “In reality, the subcloud layer departs slightly from adiabaticity due to entrainment of drier air from above and the partial compensation of temperature and moisture tendencies by turbulent mixing \citep{wyngaard1984top}, or due to rainfall and cold pools.”

line 155: could you explain the factor 0.13?

Thank you for raising this point. We have removed the specific numerical scaling and replaced it with a more general statement about the dependence on Bowen ratio, as the specific factor is not necessary for the argument.

Figure 2: I think that 'x' is indicating the vertical coordinate in this figure, but in the text 'z' is used?

Thank you for pointing this out. We have corrected x to z.

Figure 3: the lines appear a bit thin, thicker lines would perhaps make the figure more clear

Thank you, we have made the lines thicker.

General question about surface instability, e.g. line 299: "the near-surface air temperature is cooler than the surface, so that the layer above is convectively driven." Near-surface instability is defined by the vertical gradient of the virtual potential temperature, which depends on the temperature and the humidity. In theory surface-driven convection can be driven by a vertical moisture gradient, even if the near-surface vertical potential temperature gradient is slightly positive. Could the authors clarify whether such conditions may occur in the situations considered here?

line 317: Define GEDI right after it is mentioned (Global Ecosystem Dynamics Investigation).
Corrected, thank you, “Laser ranging using more sophisticated methods, such as employed by the Global Ecosystem Dynamics Investigation (GEDI) lidar aboard the International Space Station, could provide better estimates of cloud base height.”