The Impact of Cometary 'impacts' on the Chemistry, Climate, and Observations of Earth-like Exoplanetary Atmospheres

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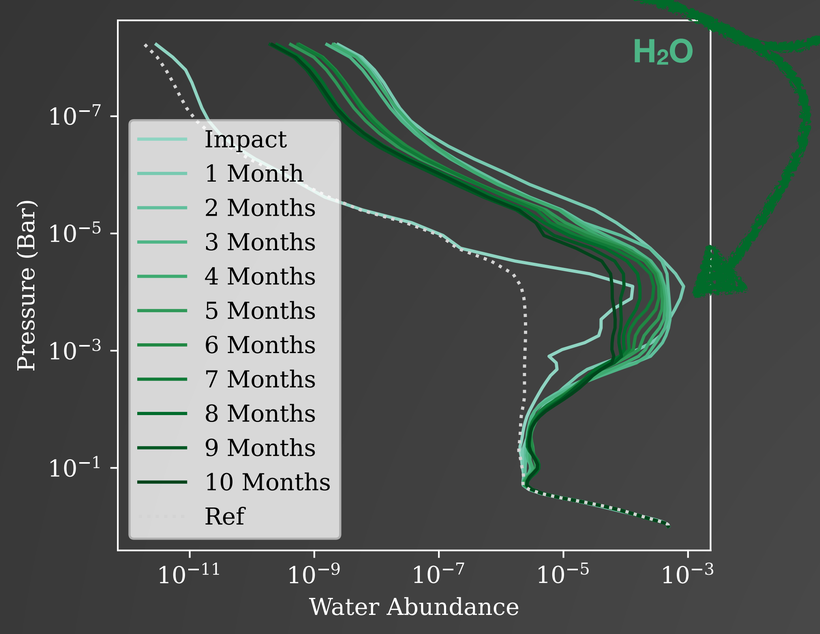
Question: How do icy cometary impacts shape the atmospheric composition and chemistry of tidally-locked, potentially habitable, Earth-like exoplanets?

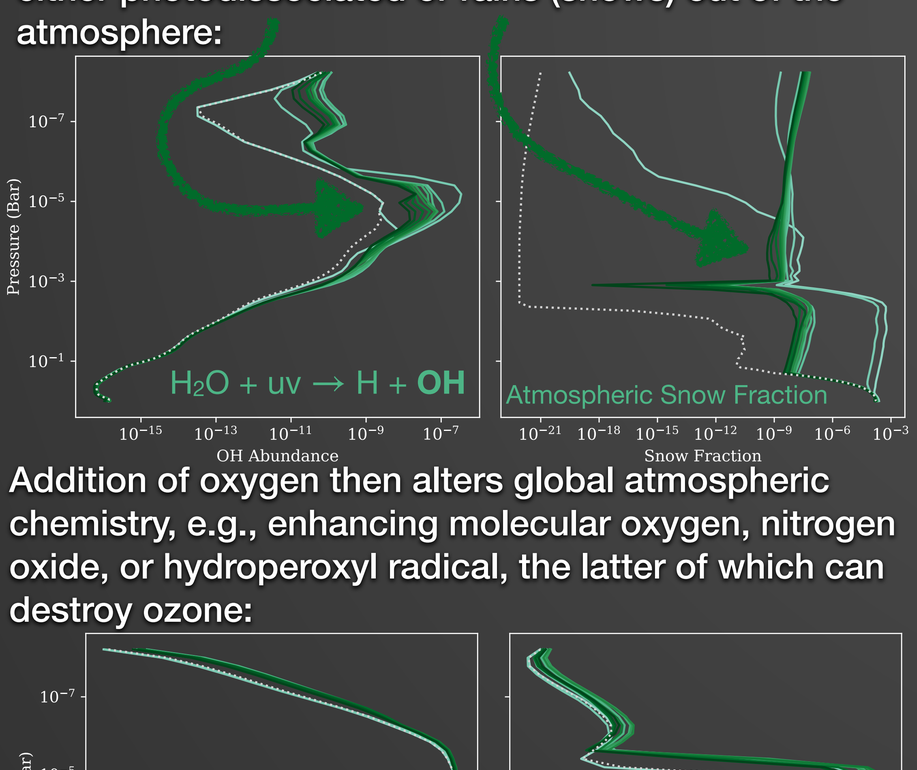
Method: Combine cometary impact and ablation model with a Earth-system model WACCM/CESM which has been modified to model the potentially habitable, tidally-locked, exoplanet TRAPPIST-1e

We model the impact of a single pure water (ice) comet with a radius of 2.5km at the sub-stellar point:

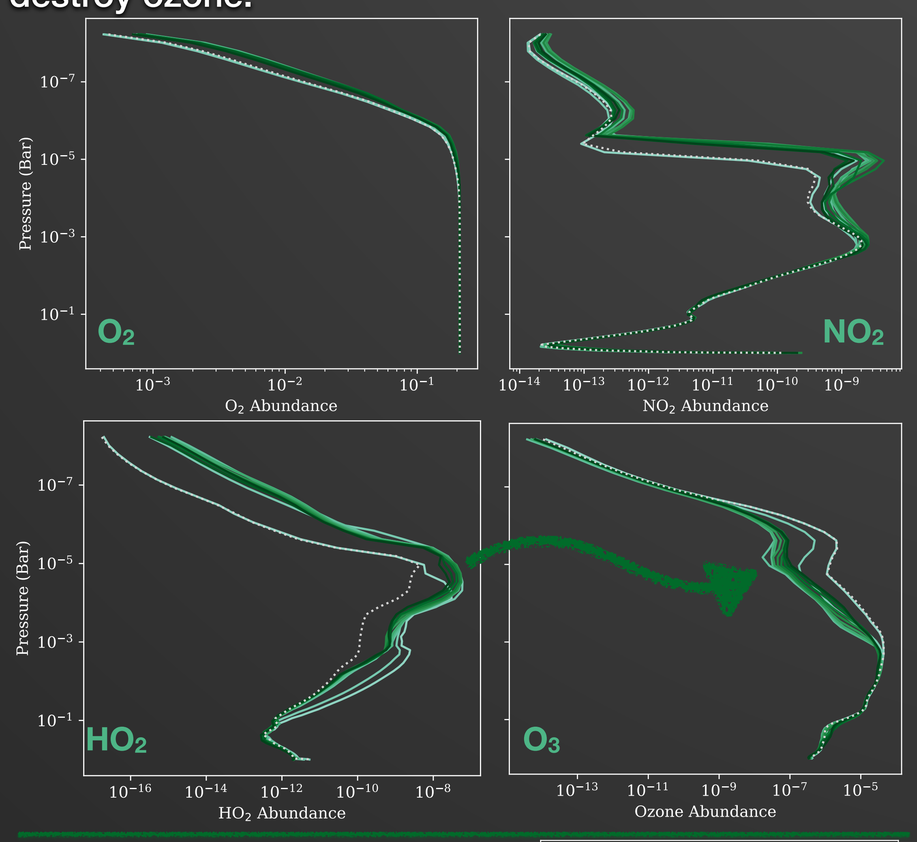


The impact occurs at the end of the first model month, hence the initial monthly mean shows a reduced water abundance.

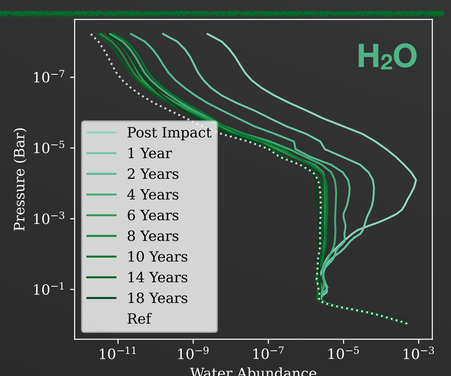
We find strong evidence that the deposited water is either photodissociated or rains (snows) out of the atmosphere:



Addition of oxygen then alters global atmospheric chemistry, e.g., enhancing molecular oxygen, nitrogen oxide, or hydroperoxyl radical, the latter of which can destroy ozone:



We find that water enhancement at low pressures persists for over 15 years!



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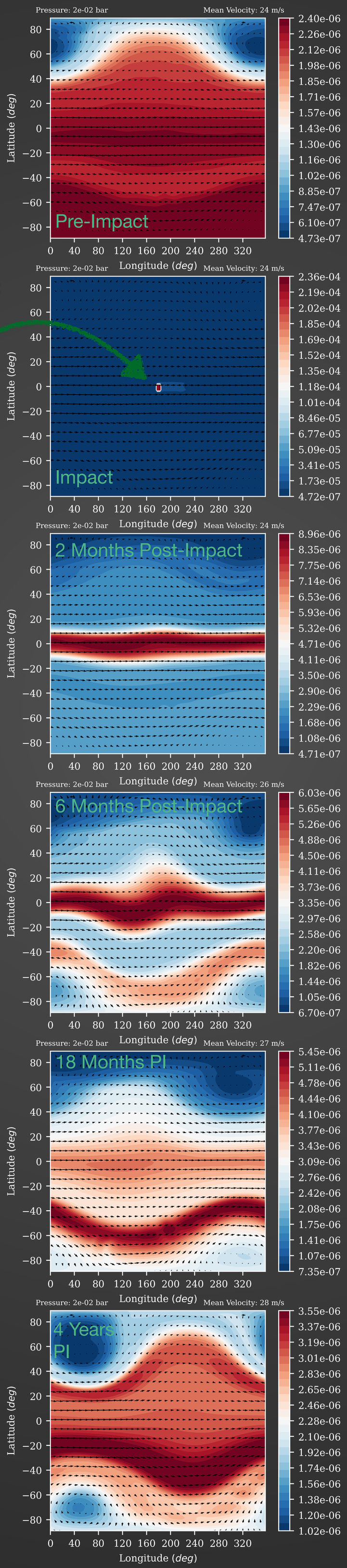
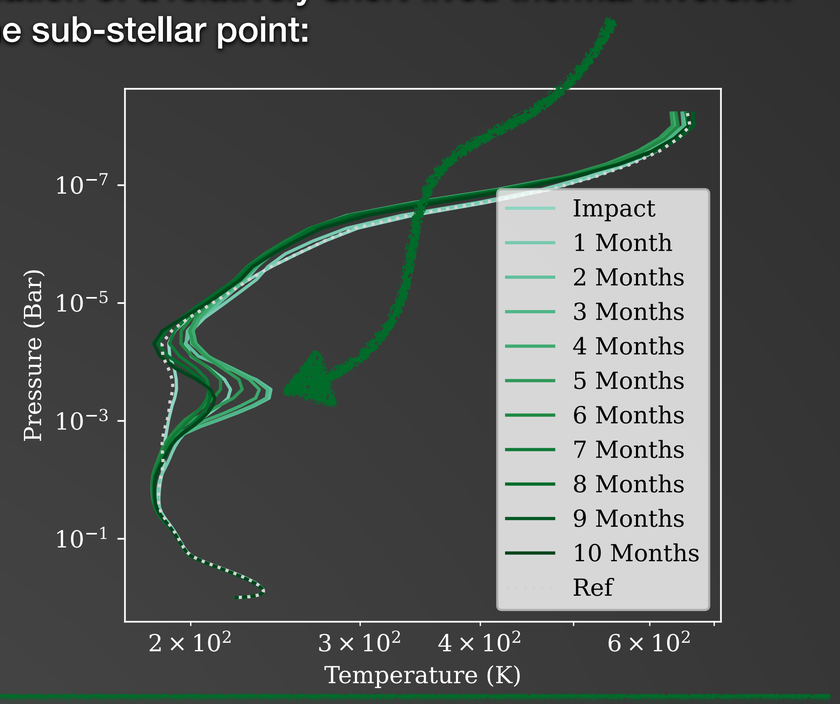
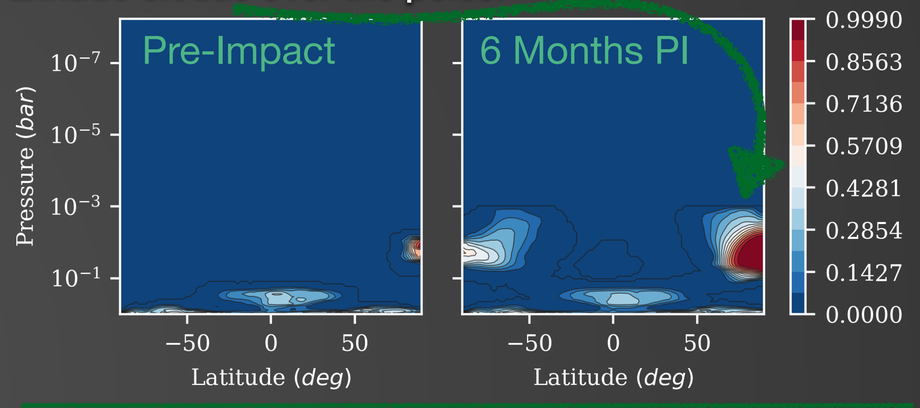


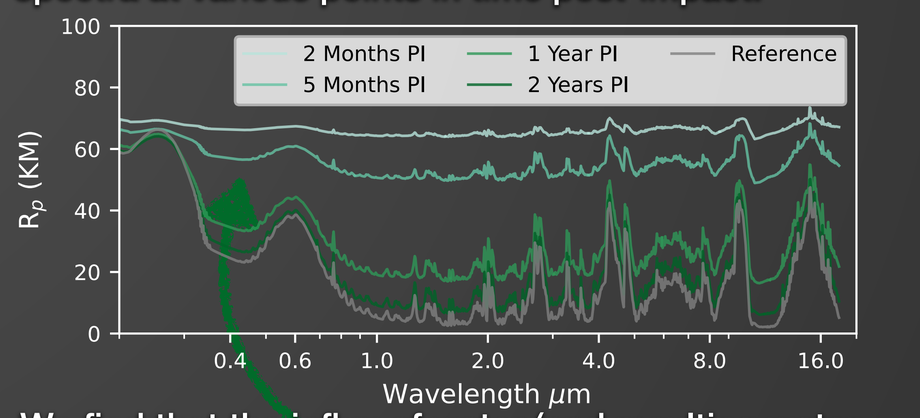
The massive enrichment in atmospheric water has has implications for the thermal properties of the atmosphere. Water acts as a strong opacity source, leading to significant day-side heating and the formation of a relatively short-lived thermal inversion at the sub-stellar point:



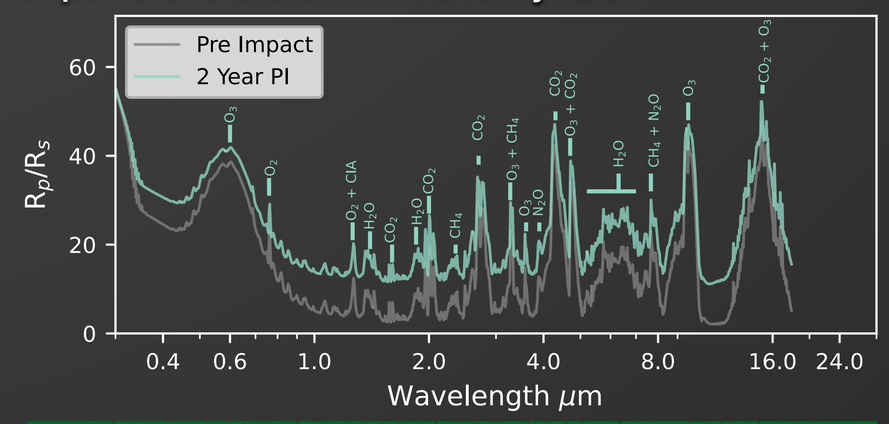
Also find that the additional atmospheric water (and ice) leads to the formation of clouds, particularly high altitude clouds over the poles:



All of these effects can potentially drive observable changes in the atmosphere. We use the planetary spectrum generator (PSG) to calculate transmission spectra at various points in time post-impact:



We find that the influx of water (and resulting water ice) acts as a strong opacity source, increasing the apparent radius of the planet from ~10 to ~70km for the first 6-12 months post impact.
As the water in the outer atmosphere is photodissociated and/or rains (snows) out, we find that the atmospheric opacity settles back towards the unperturbed state within a few years:



Preliminary Conclusions - Models and Analysis Ongoing:

- The delivery of water by even a single icy cometary impact can significantly affect the atmospheric chemistry and composition of Earth-like exoplanets, effects which have the potential to be observable for upto a decade post-impact.
- **Talk to me to learn more about how cometary impacts can also affect Earth-as-an-Exoplanet and how the impact location shapes the results!**