Reply to comment by Roderick regarding HESS Manuscript
https://egusphere.copernicus.org/preprints/2025/egusphere-2025-2814

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I agree with the comments made by Dr. Roderick, but only with regard to the narrow range of state conditions within which they are valid, even if those accurately describe the majority of Earth's evaporating, open-water surfaces.

Dr. Roderick's numerical example, where water vapour reaches a 2% molar fraction (χ_v), does indeed represent "reasonably warm moist air", but is quite dry relative to tropical surface conditions. Extremely sultry environments reach χ_v = 5% (Raymond et al., 2020), where practical differences between our calculations begin to emerge. Also, the Earth's hydrological system includes open-water surfaces whose temperatures exceed 60ºC, sometimes to 70ºC (Jaworowski et al., 2013), and whose extreme evaporation rates may be of interest. Air humidities in the non-turbulent layer above such surfaces far exceed that of Dr. Roderick's example. There, the fraction of water vapour transport that is not diffusive is significant, as is the difference in its estimation based on molar- versus mass-fractions (see Table 1 and Figure 1 below). Finally, the factor (~18/29) cited by Dr. Roderick increases with increasing humidity, since 29 g mol^{-1} is not an accurate molecular mass for very humid air. This factor reaches unity at the boiling point, where air is water vapour.

Variable	p	T	T	e_s	χ_v	ρ_v	p_d	ρ_d	ρ	q
Units	mb	K	ºC	hPa	%	g m^{-3}	hPa	g m^{-3}	g m^{-3}	%
	1014.2	273.16	0.01	6.12	**0.60**	4.85	1008.08	1285.65	1290.50	**0.38**
	1014.2	283.15	10.00	12.28	**1.21**	9.40	1001.92	1232.70	1242.10	**0.76**
	1014.2	293.15	20.00	23.39	**2.31**	17.29	990.81	1177.45	1194.74	**1.45**
	1014.2	303.15	30.00	42.47	**4.19**	30.36	971.73	1116.68	1147.04	**2.65**
	1014.2	313.15	40.00	73.85	**7.28**	51.10	940.35	1046.12	1097.21	**4.66**
	1014.2	323.15	50.00	123.52	**12.18**	82.82	890.68	960.20	1043.02	**7.94**
	1014.2	333.15	60.00	199.46	**19.67**	129.73	814.74	851.96	981.69	**13.21**
	1014.2	343.15	70.00	312.01	**30.76**	197.01	702.19	712.87	909.89	**21.65**
	1014.2	353.15	80.00	474.14	**46.75**	290.91	540.06	532.75	823.66	**35.32**
	1014.2	363.15	90.00	701.82	**69.20**	418.74	312.38	299.67	718.41	**58.29**
	1014.2	373.15	100.00	1014.20	**100.00**	588.91	0.00	0.00	588.91	**100.00**

Table 1. Comparison of water vapour's molar (χ_v) and mass (q) fractions over an extreme humidity range. Pressure (p) is specified as 1014.2 mb, as are temperatures (T). Saturation vapour pressure (e_s) is from Haynes et al. (2014); for simplicity, 100% relative humidity is assumed. The ratio e_s/p determines χ_v. The ideal gas law calculates ρ_v as $e_s/(R_v \cdot T)$ where R_v = 461.52 J kg^{-1} K^{-1} and also ρ_d as $p_d/(R_d \cdot T)$ where R_d = 287.05 J kg^{-1} K^{-1}, and p_d is the partial pressure of dry air from Dalton's law (p - e_s). The air density (ρ) is the sum of those of water vapour and dry air ($\rho_v + \rho_d$). Finally, the specific humidity (q) is the ratio of ρ_v to ρ. (Note that hydrothermal features in Yellowstone National Park have lower surface p, and therefore even higher fractions of water vapour than those corresponding to their temperatures in this table.)

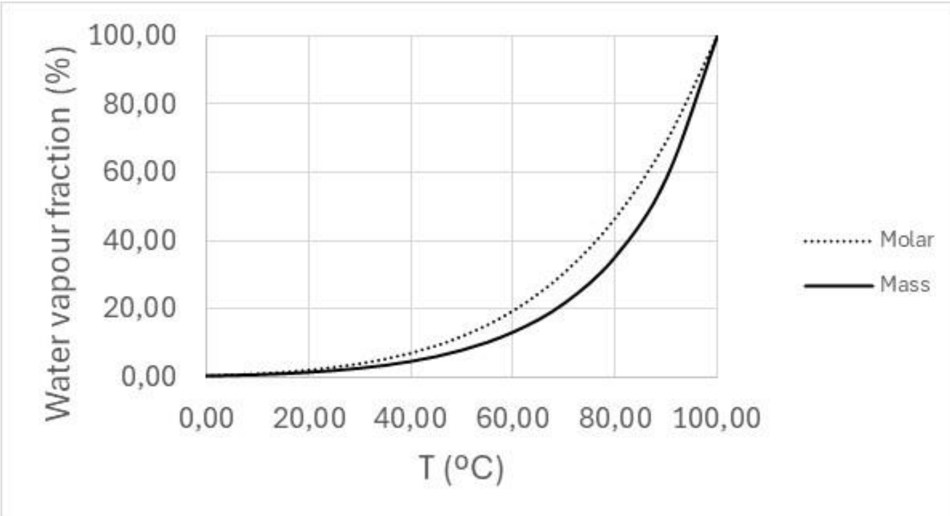

Figure 1. Graphical comparison of water vapour's molar (χ_v) and mass (q) fractions over an extreme humidity range (data from Table 1 above).

References

Haynes, W.M., Lide, D. R., and Bruno, T. J., *CRC Handbook of Chemistry and Physics*, Taylor and Francis, Boca Raton, 2014.

Jaworowski, C., et al., Temporal and seasonal variations of the hot spring basin hydrothermal system, Yellowstone National Park, USA, *Remote Sens.,* ***5***, 6587-6610, https://doi.org/10.3390/rs5126587, 2013.

Raymond, C., Matthews. T,. and Horton, R.M., The emergence of heat and humidity too severe for human tolerance, *Sci Adv* **6** eaaw1838. https://www.science.org/doi/10.1126/sciadv.aaw1838, 2020.