Supplement information for:

Interannual variations and future changes in the soil uptake of hydrogen

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Text S1

Tables S1–S2

Figure S1–S8

Text S1: Details of the deposition velocity scheme:

The sensitivity to soil moisture, f is expressed as

$$f(s) = \frac{1}{N}(s - s_{ws})^{\beta 1}(s_{up} - s)^{\beta 2}$$

here s is the ratio of the soil volumetric moisture content to the soil porosity, s_{ws} and s_{up} are the soil-dependent lower and upper moisture thresholds for bacterial activity, respectively; and *N* is a normalization factor such that max(*f*) = 1. s_{up} is taken as 1, and s_{ws} is estimated as

$$s_{ws} = \left(\frac{\psi}{\psi_{ws}}\right)^{\frac{1}{b}}$$

where constants ψ and b can be determined experimentally *(Bertagni et al., 2021)* and ψ_{ws} is the soil matrix potential below which bacterial uptake is inhibited. Given s_{ws}, $\beta 1$ and $\beta 2$ can be estimated based on observational constraints *(Bertagni et al., 2021)*. $\beta 1 = 0.4$ and $\beta 2 = \beta 1(1 - s_{opt})/(s_{opt} - s_{ws})$. s_{opt} is an optimum moisture condition that maximizes the bacteria metabolic rate. s_{ws} and s_{opt} for different soil types are shown in Table S1 from *Bertagni et al. (2021)*.

Table S1. Moisture thresholds (S_{ws}) for biological activities, calculated by the function of s_{ws} in Text S1 with ψ_{ws} equals to –3000 kPa (for S1) and –10000 kPa (for S2).

Soil type	S_{ws} standard (S1)	S_{ws} lower (S2)
Sand	0.11	0.08
Loamy sand	0.11	0.08
Sandy loam	0.18	0.14
Silt loam	0.31	0.24
Silt	0.31	0.24
Loam	0.24	0.19
Sandy clay loam	0.32	0.27
Silty clay loam	0.37	0.32
Clay loam	0.45	0.39
Sandy clay	0.44	0.39
Silty clay	0.49	0.43
Clay	0.52	0.47

Table S2. Uncertainty range for snow depth from GLDAS.

Snow class	Depth range[a]	GLDAS STD[b]
Tundra	10–75	13.4
Taiga	30–120	10.0
Maritime	75–500	9.1
Ephemeral	0–50	2.2
Prairie	0–50	5.3
Alpine	75–250	9.1

[a] *Sturm et al. (1995)*

[b] *Qiao et al. (2022)*

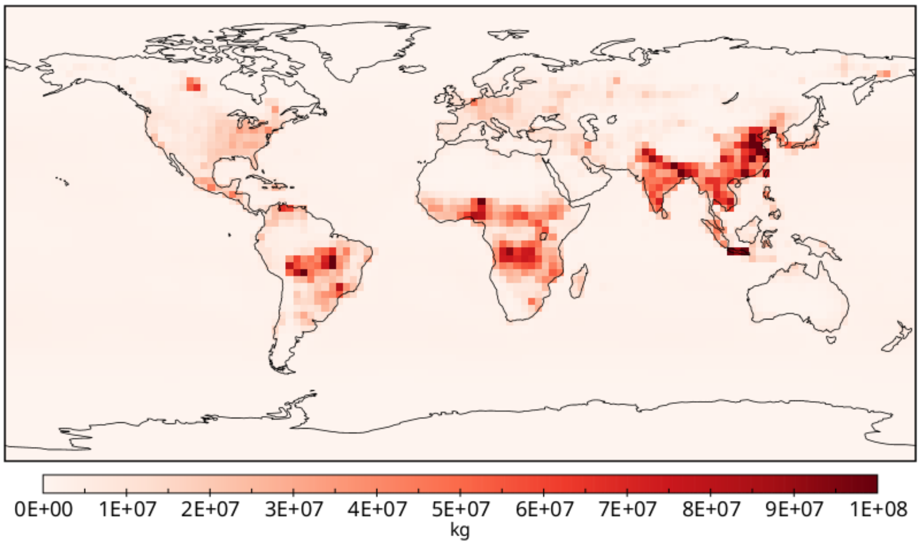

Figure S1. Global distribution of annual H_2 emissions in 2010 (kg/grid/yr) used in the model simulations.

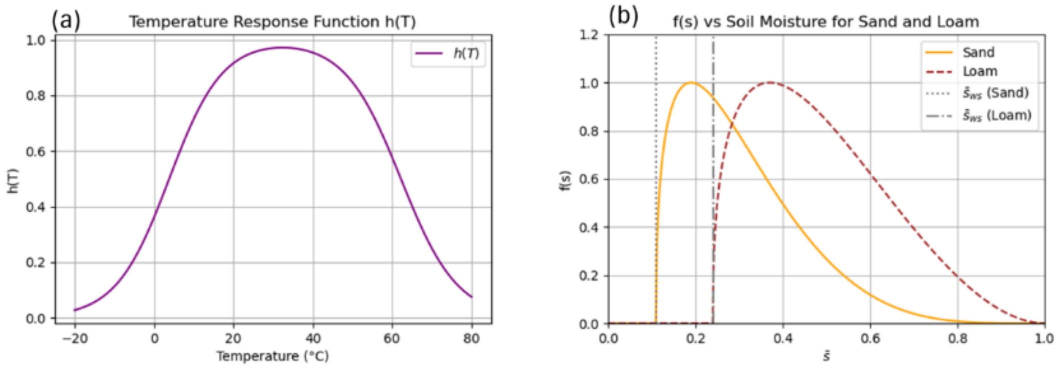

Figure S2. (a) Soil temperature dependence (hT) and (b) soil moisture dependence (f) for sand and loam soil types used in calculating deposition velocity Vd.

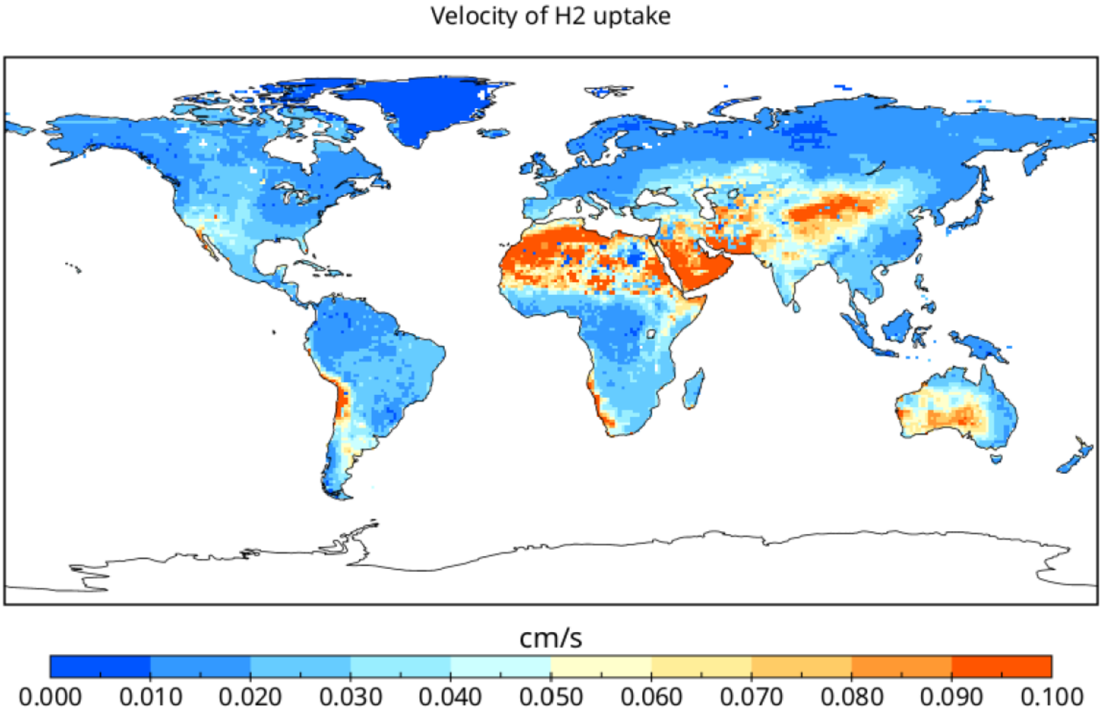

Figure S3. Distribution of annual mean H_2 deposition velocity in 2010 using Scheme S2 with consideration of canopy and litter resistance, and with lower moisture thresholds for different types of soil.

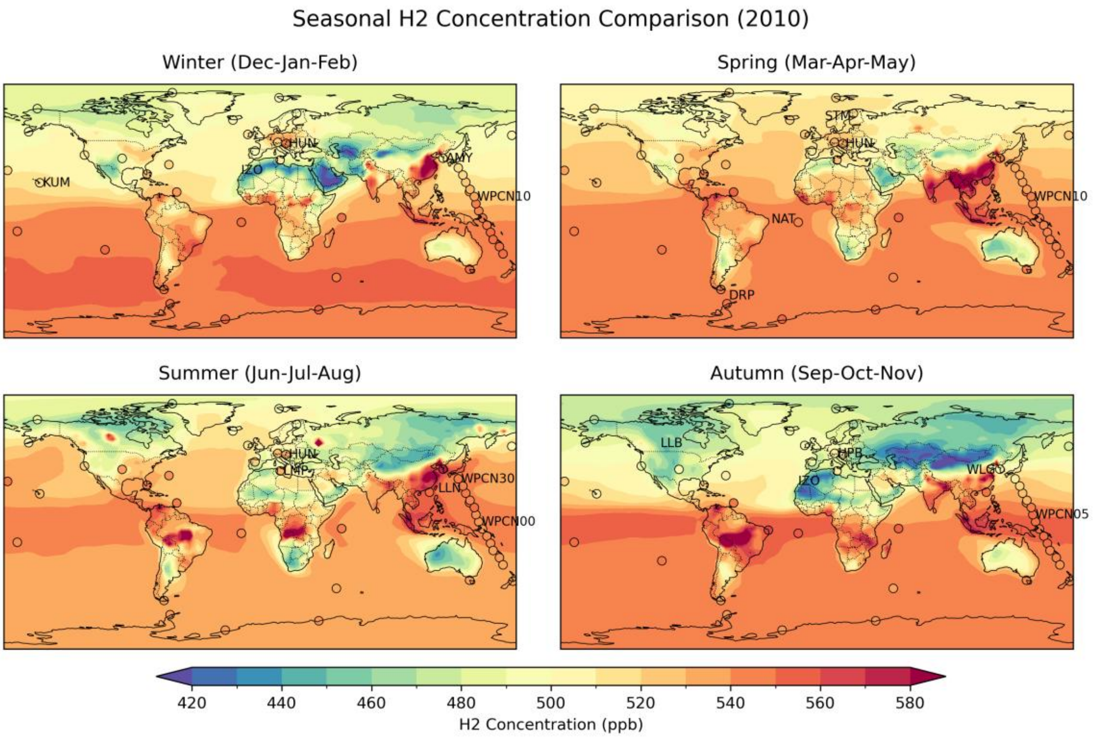

Figure S4. Comparison of simulated seasonal concentrations of H_2 in 2010 in the lowest model level (shading) with surface observations (spots, altitudes below 500 m). Observed seasonal mean H_2 is shown for locations with at least two valid monthly measurements.

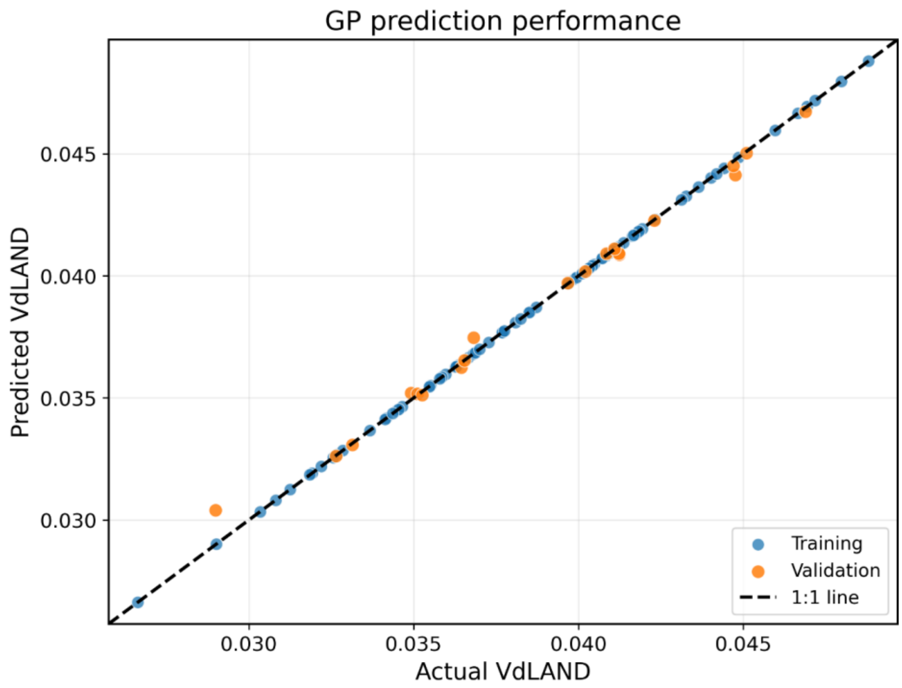

Figure S5. GP emulator performance in predicting annual mean H_2 deposition velocity over land.

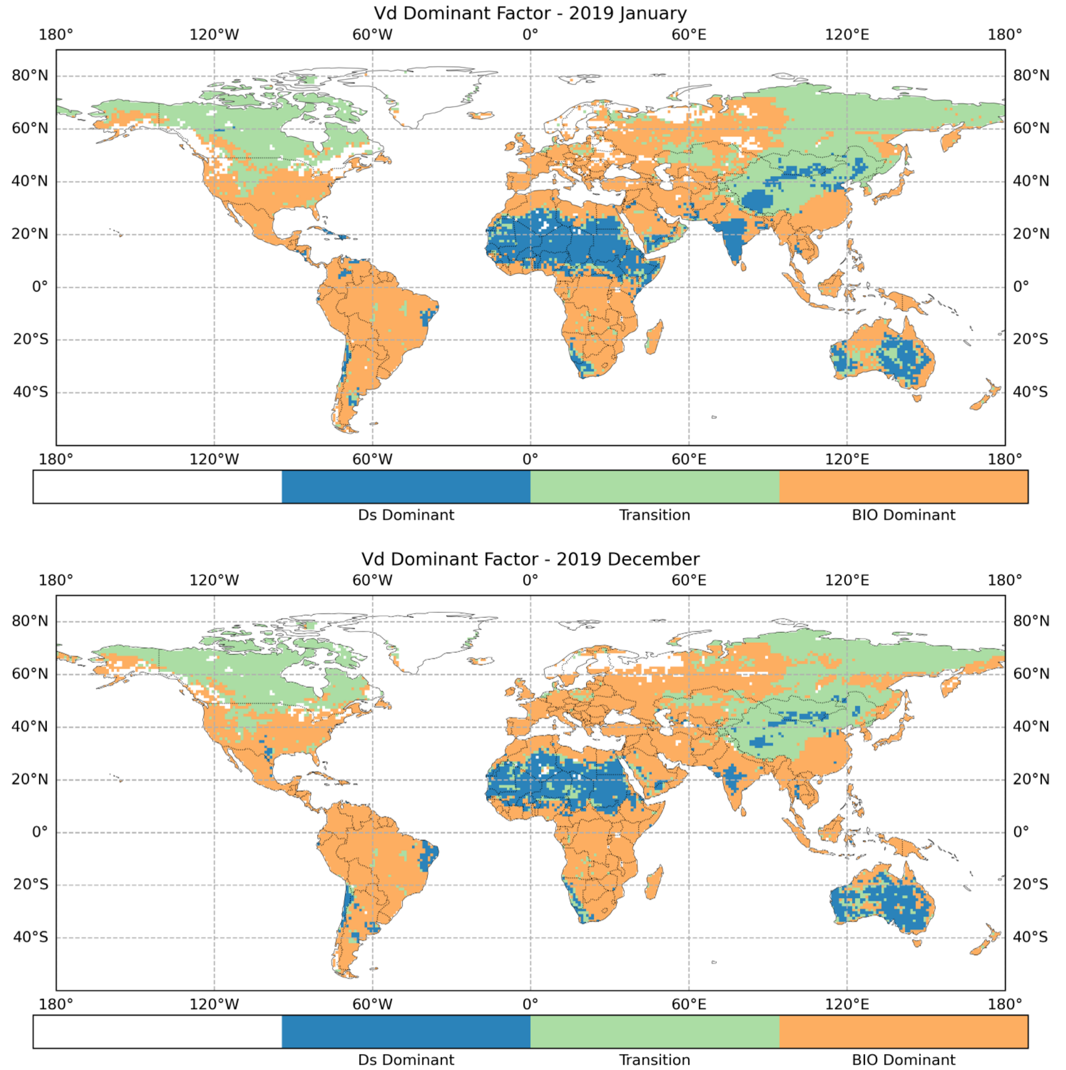

Figure S6. Dominant factors controlling the sensitivity of H_2 dry deposition velocity to soil moisture variations in January and July 2019 showing the regions governed by diffusion (blue), biological (orange) and transition (green) regimes.

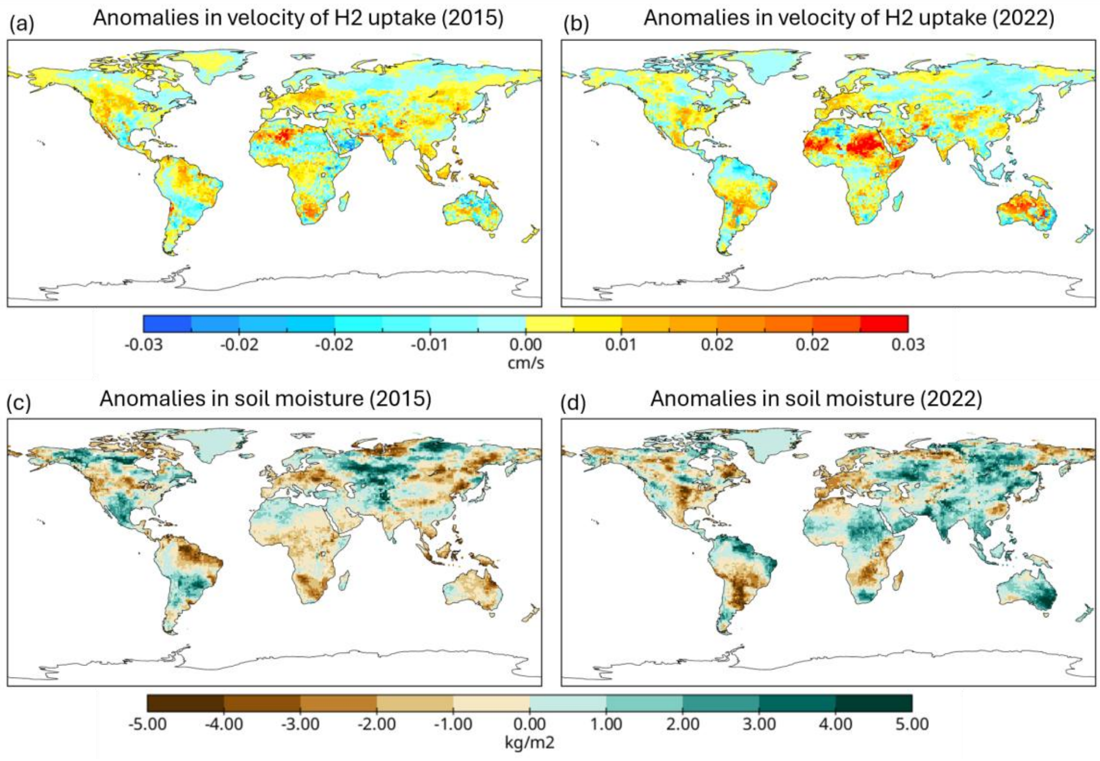

Figure S7. Anomalies in annual mean H_2 deposition velocity and soil moisture (relative to the 2010–2022 mean) in 2015 and 2022.

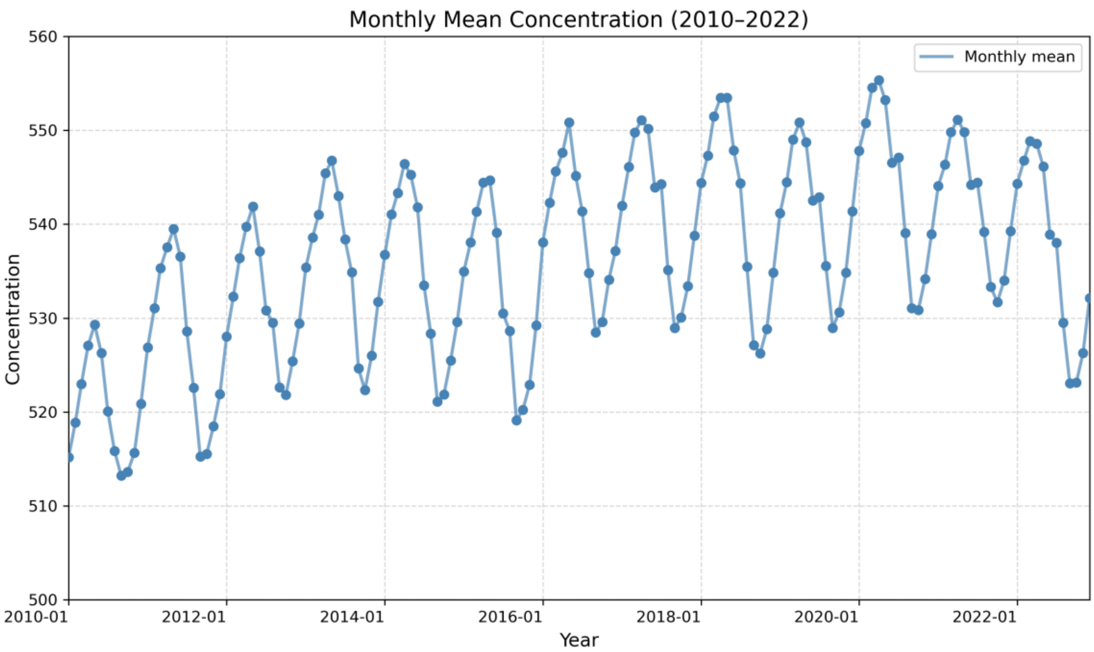

Figure S8. Simulated monthly variation in surface H_2 mixing ratios (ppbv) from the "Soil-Modified" experiment at background sites from 2010 to 2022.

References:

Bertagni, M. B., Paulot, F., and Porporato, A.: Moisture fluctuations modulate abiotic and biotic limitations of H2 soil uptake, Global Biogeochemical Cycles, 35, e2021GB006987, https://doi.org/10.1029/2021GB006987, 2021.

Qiao, D., Li, Z., Zeng, J., Liang, S., McColl, K. A., Bi, H., Zhou, J., and Zhang, P.: Uncertainty characterization of ground-based, satellite, and reanalysis snow depth products using extended triple collocation, Water Resources Research, 58, e2021WR030895, https://doi.org/10.1029/2021WR030895, 2022.

Sturm, M., Holmgren, J., and Liston, G. E.: A seasonal snow cover classification system for local to global applications, Journal of Climate, 8, 1261-1283, https://doi.org/10.1175/1520-0442(1995)008<1261:ASSCCS>2.0.CO;2, 1995.