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The atmospheres of ultra-hot Jupiters (UHJs) are vastly non-uniform in terms of chemistry, temperature, dynamics, and cloud cover, which makes their observed spectra challenging to interpret. Resolving their transmission spectra as a function of time provides crucial insights into the “3D nature” of these planets. We present the first ever time-resolved water and CO absorption signals of an UHJ, based on three transits of WASP-121b observed with GEMINI-S/IGRINS at high spectral resolution. While CO absorption remains equally strong during the transit, the water signal displays significant variation, suggesting water dissociation or cloud formation on one of the limbs of the planet. Also, both molecules display different Doppler shifts, which we demonstrate are due to their unique spatial distribution across the atmosphere. We compare our observations to a suite of global-circulation models and their corresponding 3D spectra, to paint an accurate, multi-dimensional picture of the limb region of WASP-121b.