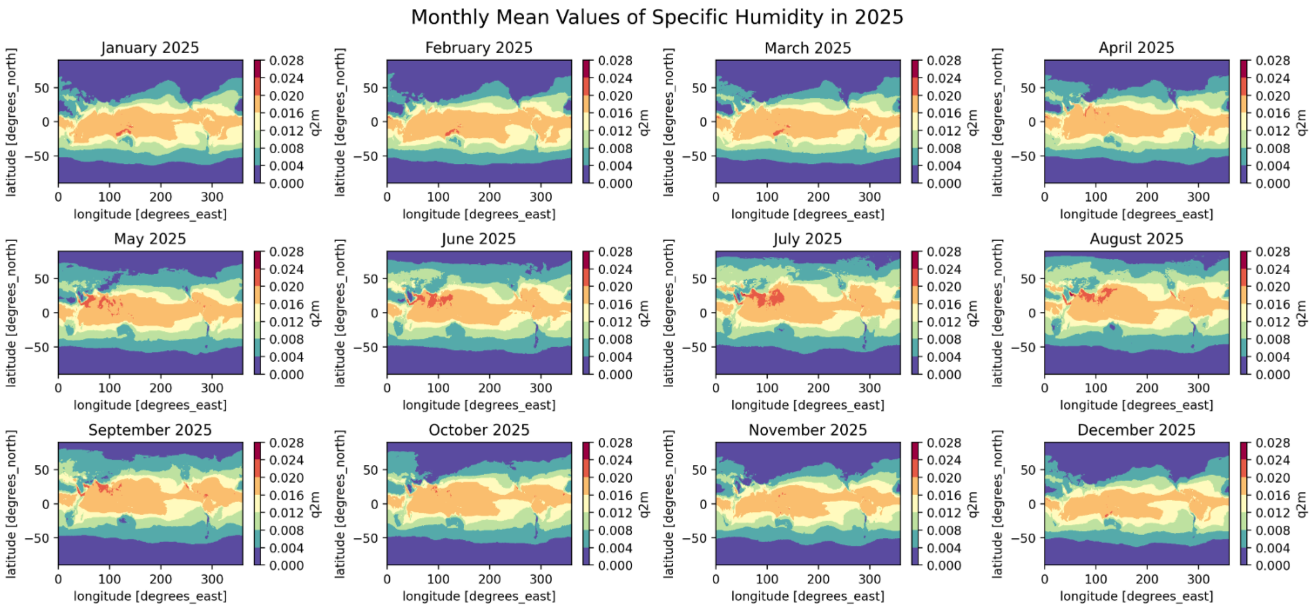


From a scientific perspective, what can you say about the global distribution of specific humidity as well as their seasonal cycle? What hypotheses could you develop to explain what you see?

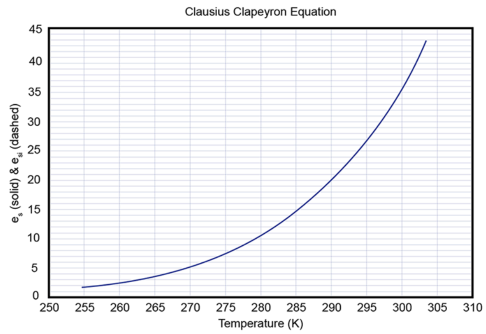
In terms of the global distribution of specific humidity, specific humidity increases as you move toward the equator and decreases as you move toward the North and South poles. In terms of the seasonal cycle, areas above 0 degrees latitude have lower humidity in the December through February period (Northern Hemisphere winter) in comparison to the June through August period (Northern Hemisphere summer). Two particularly interesting areas are 50-150 degrees longitude and 0-50 degrees latitude where specific humidity jumps to very high values (around 0.024). This is the monsoon season for this area. Additionally, 100 to 150 degrees longitude and -25 to 0 degrees latitude have the opposite trend where specific humidity is high in the December through February period which decreases into the June through August period. This is the monsoon season for this area (including Australia). This is because seasons are opposite for places below/above the equator. In other words, the hemispheres have opposite seasonal cycles. Both of these areas of extremely high humidity exist around the same longitudinal values. This is due to the Indo-Pacific warm pool which consists of extremely high sea surface temperatures which increases the rate of evaporation leading to a lot of water in the atmosphere (and therefore high specific humidity) which is also responsible for the monsoon season that these regions experience. Therefore, trends in specific humidity that have to do with latitude values are likely seasonal. Alternatively, longitudinal changes can reveal more about other weather patterns and phenomena.

Another interesting question would be: what else metrics could be used to describe humidity/drought besides specific humidity? You could find this either from your life experience or text books. Could you also find the relationships among these quantities?

Other metrics that could be used to describe humidity/drought other than specific humidity:

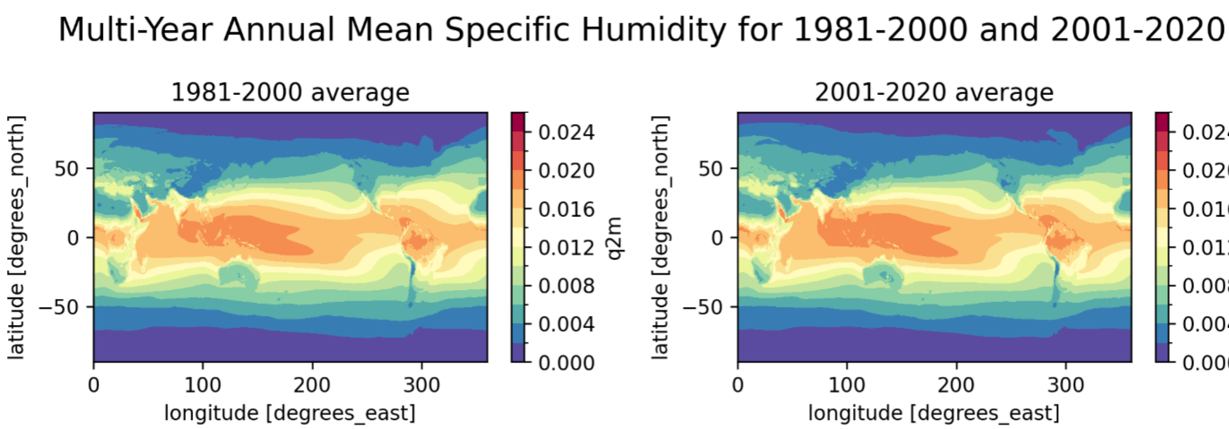
- Dew point
    - absolute measure of water in the air
    - temperature of air to be cooled before it turns into a liquid (water vapor condenses to liquid water)
    - Experimentally measured by the wet bulb method
    - Not temperature dependent
- relative humidity
    - amount of water vapor that the air is holding compared to what it can hold at maximum capacity.
    - $RH = \frac{e_a}{e_s(T_a)}$
    - e_s = Saturation vapor content of air at temperature T_a
    - e_a = actual vapor pressure
    - not an absolute measure (because it is a ratio)
    - highly temperature dependent
- Vapor Pressure deficit
    - drying power of air
    - $VPD = e_s(T_a) - e_a$
    - An absolute measure.
        - For a given RH, VPD can vary greatly because of the exponential relationship between temperature change and saturation vapor pressure.
    - Also temperature dependent.
        - A change in temperature at low temps does not increase saturation vapor pressure as much as it does at high temperatures because of the exponential relationship between temperature and saturation vapor pressure.
        - This is according to the The Clausius-Clapeyron Equation.
        - $ln(\frac{P_2}{P_1}) =- \frac{\Delta H_{vap}}{R}(\frac{1}{T_2} - \frac{1}{T_1})$
        - P1 and P2 Vapor pressures at Temperatures T1 and T2 (Kelvin)
        - ΔH_{vap} is enthalpy, or heat, of vaporization (Joules/mol)

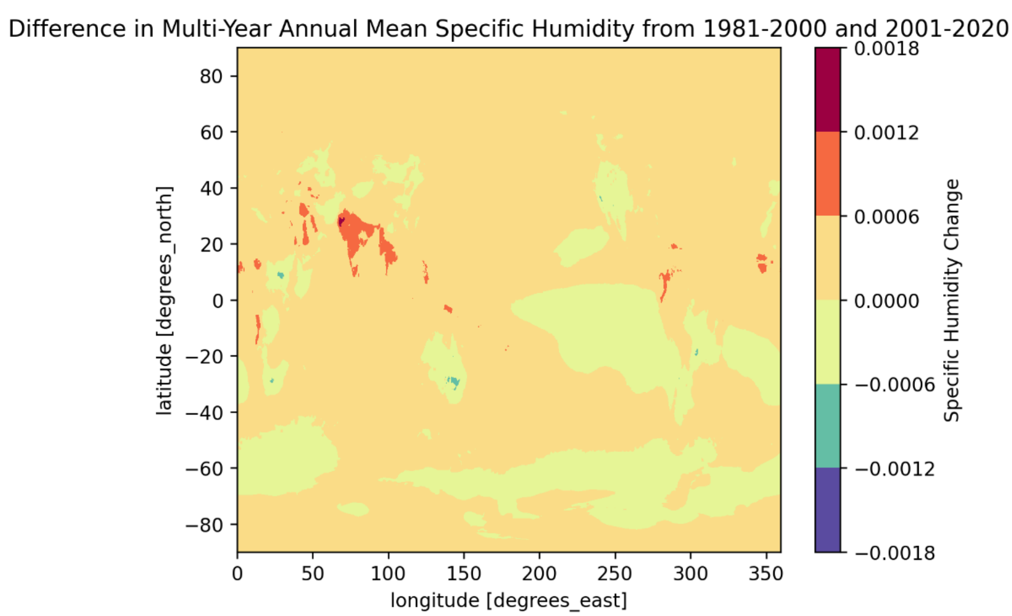
- R is ideal gas constant (8.314 Joules/Moles*Kelvin)

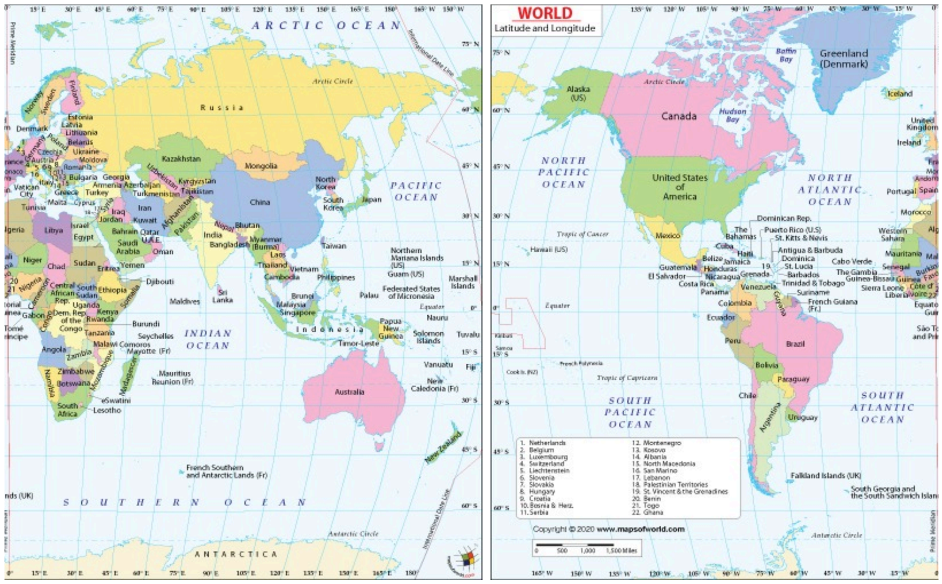


https://courses.ems.psu.edu/meteo300/book/export/html/584

While thinking about these questions, you could also try a more challenging task: make multi-year annual mean specific humidity for both 1981-2000 and 2001-2020, and also their difference. Is there any interesting trend pattern from the result?







Northern Hemisphere:

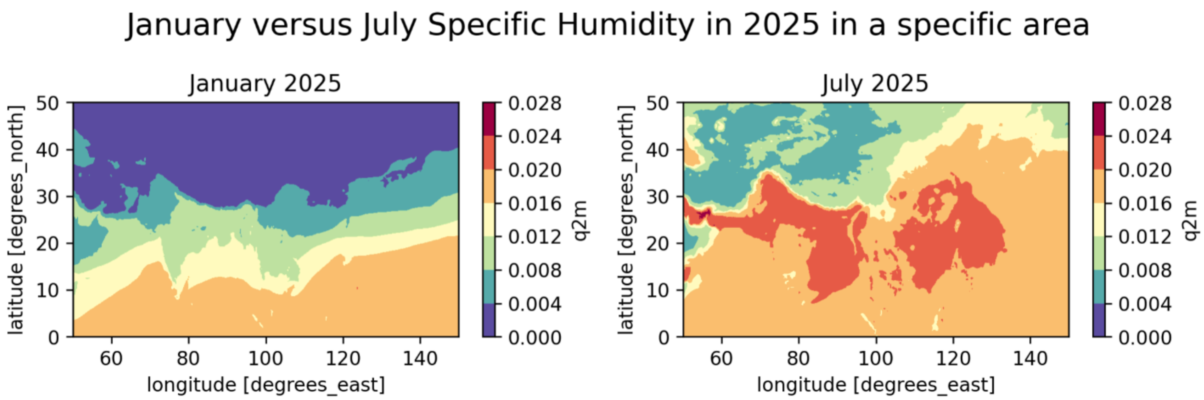
- Almost all of the northern hemisphere's specific humidity increased slightly over time
- India, Nepal, Bhutan, Myanmar and some surrounding territories have isolatedly increased much more significantly than the rest of the world

Southern Hemisphere:

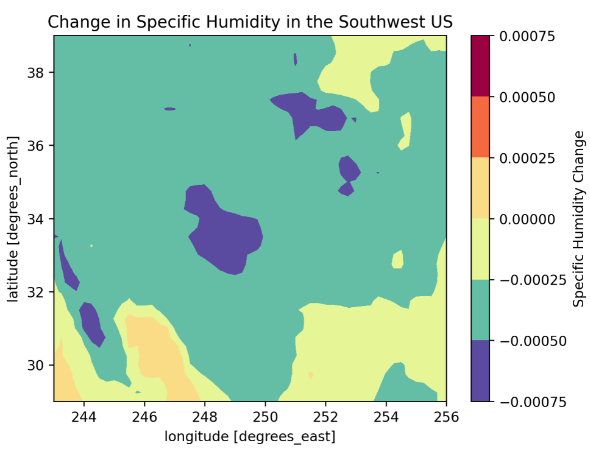
- About 70 percent of the area has increased specific humidity but there are significant portions of decreased specific humidity. Both the increases and decreases are around the same amount.

These results are consistent with the research about VPD that I have been seeing. To explain, since temperatures are rising, the saturation vapor pressure (or the amount of water the air can hold) has increased significantly. So, we would expect the actual vapor pressure, and similarly specific humidity, to increase at the same rate as the saturation vapor pressure. Specific humidity and actual vapor pressure are analogous in this situation because they both represent the actual amount of water in the atmosphere, albeit through different methods. But, increases in specific humidity have not been the case in a lot of areas, particularly in the Southern Hemisphere. Although specific humidity has generally increased globally, there are many areas where it has slightly decreased. Additionally, in places that it has increased, it has not been very significant, and certainly not enough to keep VPD constant.

Further, the area that experienced the greatest increase in specific humidity is the same area that we see the extreme highs in specific humidity in the Northern Hemisphere's summer months. This region also saw great changes over the year which is exemplified in the following graph showing the difference in the region from January to July.



Additionally, considering one of the articles focusing on VPD specifically mentioned the Southwestern US, I plotted this area as well to see how specific humidity has changed from the 1981-2000 data to the 2001-2020 data.



(Southwest: 29-39N lat, 243-256E long)

This graph highlights why the VPD has increased so much in this region. To explain, the temperatures globally and in this region have increased significantly which raises the Saturation Vapor Pressure exponentially. But, the amount of water in the atmosphere has not matched that increasing pace. In this region, the amount of vapor in the air (shown through specific humidity) has actually decreased in the majority of the region.