Creating Science – Clouds

What are clouds made of, and how do we make them? Can we make a cloud indoors?
#CreatingScienceMakingClouds

Suggested outcomes

(NOTE: This is by no means an exhaustive list of possible outcomes, neither is it intended that ONLY these outcomes can or should be met. Science is a deeply interrelated activity, and you may find cross curriculum links you can and should use.)

Science understanding

- Earth and space sciences F - Daily and seasonal changes in our environment affect everyday life (ACSSU004)
- Earth and space sciences 1 - Observable changes occur in the sky and landscape (ACSSU019)
- Earth and space sciences 6- Sudden geological changes and extreme weather events can affect Earth's surface (ACSSU096)

Extra outcomes

- Earth and space sciences 4 - Earth's surface changes over time as a result of natural processes and human activity (ACSSU075)

Science inquiry skills

- Processing and analysing data and information 4: Compare results with predictions, suggesting possible reasons for findings (ACSIS216)
- Processing and analysing data and information 6: Compare data with predictions and use as evidence in developing explanations (ACSIS221)

Science as a human endeavour

- Nature and development of science 4: Science involves making predictions and describing patterns and relationships (ACSHE061)
- Nature and development of science 6: Science involves testing predictions by gathering data and using evidence to develop explanations of events and phenomena and reflects historical and cultural contributions (ACSHE098)

Science vocabulary words

Tier 1 (Everyday words) – clouds, wind, air, rain, weather.

Tier 3 (Specialised vocabulary)

- Torus – a ring shape. Clouds and whirlpools can both form torus shapes.
- Evaporate. When liquid water turns into gaseous, airborn water.
- Condense. When gaseous water collects back together to form liquid water. Often this is little drops you can see, such as clouds, fog or rain.
- Precipitation. When the water in the air falls out as rain.

Warning

- One way to make clouds uses the ash from a burning matchstick. Adult help required.
- The method involved here includes children jumping on closed plastic bottles. Adults should hold their hands for stability or they will fall over, often.
- FOG MACHINES ARE HOT! You can easily burn yourself on one, know how not to.
- FOG MACHINES WILL SET OFF FIRE ALARMS! Use in an appropriate, well ventilated, pre-tested area.

Preparation

- A clean, empty, plastic bottle (flexible enough to crush, such as examples here).
- Matches.
- 1/4 cup of water.
- Fog machine (not necessary, but exciting).

Learning Intent (student friendly)

'We are learning to' (WALT) understand and make clouds.

Success criteria

'What I'm looking for' (WILF) students to make a cloud and explain the science within.

Student learning goals

Help students make a self-monitored learning goal for this lesson, such as ‘make a cloud’.

Evidence of learning

How will you know when the learning goal is achieved? What EVIDENCE do you have that your students have met or exceeded the learning expectations?

Suggestions for other year levels

As always, more material is presented here than can be used by the average class during the average lesson time. However, since the students’ questions can and should guide student learning, more material is presented for your convenience.

Younger:

This activity is well suited to this age group, but will need adult help to pressurise the cloud bottle.

Children at this age can have difficulty with focus. Avoid tangents into interesting side tracts if you’re attempting to make a key point.

Middle:

This activity is well suited to this age group.

Teen:

This activity is well suited to this age group. Further mathematics may be found in the appendix for extra depth.

Engage

Play with clouds: get cloud pictures for students to enjoy, or demonstrate the cloud making device from the activity for this week. If possible, borrow a fog machine and set it up for students to explore. You can also make an airzooka and demonstrate the *torus* as the air flows out from the end.

- Make sure all students write down any questions they may have generated during this phase regarding the topic for today.
- Ask students: what is a cloud?

Explore

Activity: Humidity

Ask: Is there water in the air?

- Set out two clear plastic cups (glass works too but takes longer). Fill them both with room temperature water, and put ice in *one* of them.
- Observe for 5 to 10 minutes (the activity will not work well in extremely hot, dry, windy conditions). Have students state their observations.
- Inference: have students *explain* their observations. This is the heart of science – theory generation (and testing). That is, what are they explanations as to why only one cup has water on it?

Explain

The cold cup collects water on the outside because: There is water in the air.

You might notice the cup with cold ice begins to form water drops on the outside. Why is this so? The water didn't come through the cup at normal temperature, so where did the water come from? Perhaps it came from the very air around us? We call the amount of water in the air *humidity*. High humidity causes rain, and low humidity contributes to things like cracked lips, more static electricity and days that seem cooler because sweating is more effective! Yes, there's water in the air![1]

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[1] So why don't we drown? Gaseous water behaves differently than liquid water, and it's a LOT more spread out. Fascinatingly, in order for our lungs to absorb oxygen they need to be lined with a little layer of liquid water – but not too much or we will suffocate!

Ask:

- Can we feel the water in the air? YES, it's called humidity! On wet, sticky days there's a lot of water in the air, and so sweating isn't as effective at keeping us cool. On dry days there's not much water in the air, and it's easier to stay cool, but some people's lips can become dry and cracked.

Elaborate

How much water can the air hold?

Answer: quite a bit. The average room might have a litre or two floating around – no kidding. The school hall might even have several bathtubs' worth of water in the air!

Remember: the HOTTER the air, the more water it can hold.

- That was why when our cup got cold, water in the air came out and condensed on the side of the cup!

So what happens when air can't hold any more water? We get clouds.

And what happens when we go beyond that point? We get rain.

- Ask students if they can design new ways to test this explanation Is it really sufficient? Can they think of further or better explanations, and the experiments needed to test them?

Activity: Making a cloud in a bottle

- Practice making clouds in a bottle using a simple cloud in a bottle activity – great to get kids stomping around.

You will need:

- A large, clear, clean flexible yet strong plastic bottle. Lid must fit in tightly and securely.
- A tiny splash of water, ¼ of a cup will usually do.
- Matches.

How to make a cloud with THREE ingredients;

1. Water – put a little puddle in the bottle, lid on tightly, and shake vigorously.
2. Rain "Seeds" – put a little chalk or ash in the bottle for the drips to form around. A newly extinguished match usually smoulders for a bit, perfect. Rain 'cleans' air.
3. Lowering the temperature – sudden decompression cools the air down, letting water gather around the seeds, making clouds!

Explanation: Squishing the bottle actually makes it heat up just a tiny bit. Thus, releasing your squish suddenly cools the air in the bottle down. As the air is suddenly cooler, it can hold less water, and the water comes out as drops. As the temperature slowly returns to normal up, the drops evaporate back into the air.

For High School Students

So how does this happen in nature?

The higher you go into the sky, the cooler it gets – this is because since there is less air above you the further you go up, the less pressure there is, and the cooler you tend to get. Also, the sun does not heat the lower air up much: the sun heats up the ground, which then heats up the air by direct contact. So the higher you go, the cooler it gets, till quite suddenly you can reach a condensation point and we get clouds.

And yet, to turn gaseous water into liquids you need to *loose* heat – which results in the nearby air heating up just a little. One reason clouds stay up is because they are just a tiny bit warmer than the surrounding air! Yet hot air rises, and thus cools, so clouds quickly become some very complex things.

Activity: Bottle rockets

Set off some bottle rockets to demonstrate clouds due to air pressure drop (see our upcoming book Dangerous Science!)

After returning to the ground you will often note that the bottle rocket has a small cloud inside, caused by the sudden drop in temperature as the gasses inside expanded in order to launch the rocket.

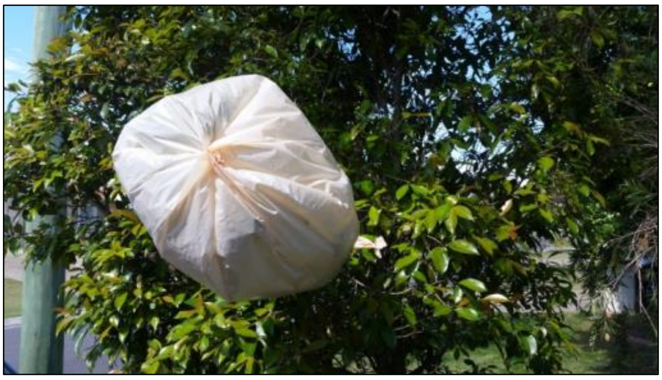
Activity: Cloud in a cold box

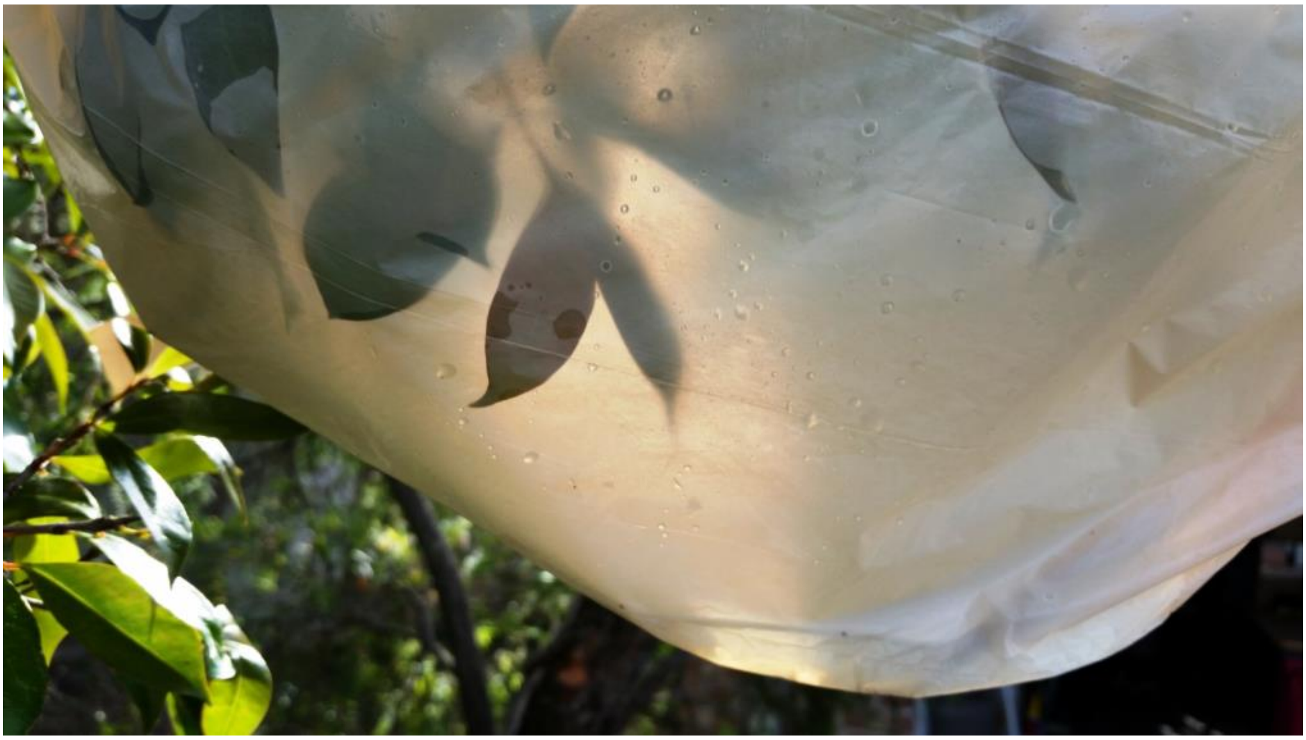
If the humidity and temperature are just right, you can make a cloud anywhere!Try blowing the moist air from your lungs into a cold, cold freezer – does it form a cloud right away?

Sometimes you can see that cloud forming as the cold air flows away from the freezer each and every time you open it. Another great reason to keep the freezer door closed!

Activity: Transpiration

Another fun and interesting thing you can do involves simply placing a clear plastic bag around a leafy branch of a tree. Make sure you tie it well so no air can get in or out. After only one day you can begin to see liquid condensing in the bag and collecting on the bottom. Where did the water come from? Well, the most accepted theory (or something) is that the roots are absorbing the water, and the leaves are 'sweating' it out through small holes (called *stomata* – blocking them even with paint can 'suffocate' a plant). What use does this have (apart from cooling the plant?) Can we suggest that the water carries other things with it, like nutrients from the soil, to fertilize the entire plant? It's called transpiration and it's one of the main reasons plants can be so tall - pushing water up a 30 meter tree is almost impossible, but pulling it up is much easier.





Evaluate

How can clouds be helpful?

- They make it rain, and rain cleans the air.
- They help balance the planet's temperature by reflecting extra sunlight and heat away form earth, and keeping the heat in when we need it.

How can clouds be dangerous?

- They are hard to see through and can hide terrible dangers.
- They can make lightning.
- They can clean the air of toxic chemicals – and spread them on the ground as acid rain.

Review with students what they felt they learnt from this lesson. Did they have any questions at the start that they feel were answered?

Success criteria

- Review the Learning Intentions of this lesson with students. Was it met?

At the end of each class, review the learning objective and see how we did. Ask:

- ⇨ Did you achieve your learning goal?
- ⇨ What did You learn?
- ⇨ What worked to help you achieve it?
- ⇨ What might you do better next time?
- ⇨ (If needed) where can you go for extra help or information?

Assessment

Prior learning:

Take time to focus on planned content material during the engage phase, for example, what are clouds made out of? Does the air have water in it?

Formative:

Research clouds:

- What are clouds made out of? What kinds are there?
- Who came up with the current descriptions of cloud shapes?
- Can you find out how far away clouds are?

Research Rain:

- How can rain be useful?
- How can rain be dangerous and damaging?
- How does rain help shape the land and sea?

Summative:

Give a presentation, written or spoken, about what clouds are and how they are made – then demonstrate making a cloud.

Help students consider ways they can communicate their new understanding to others, just as scientists need to do.

So what?

- The air has water in it.
- Clouds are made from water (not cotton wool, or sheep).
- Cooling the air down suddenly can make the water come out of it, and make clouds and rain.
- Rain can change the land and sea.

Creating science

Science understanding

As students made and explained their own clouds, they found that:

- Earth and space sciences F - Daily and seasonal changes in our environment affect everyday life (ACSSU004)
- Earth and space sciences 1 - Observable changes occur in the sky and landscape (ACSSU019)
- Earth and space sciences 6- Sudden geological changes and extreme weather events can affect Earth's surface (ACSSU096)

Extra outcomes

- Earth and space sciences 4 - Earth's surface changes over time as a result of natural processes and human activity (ACSSU075)

Science inquiry skills

As we explored the humidity gathering around the icy cup, and learned how to make our own clouds, we saw that;

- Processing and analysing data and information 4: Compare results with predictions, suggesting possible reasons for findings (ACSIS216)

As we used this information to explain transpiration in plants we managed to;

- Processing and analysing data and information 6: Compare data with predictions and use as evidence in developing explanations (ACSIS221)

Science as a human endeavour

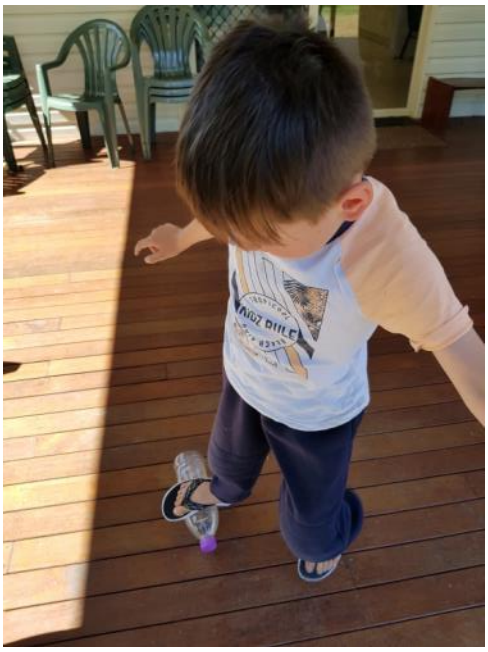
Exploring clouds, what they're made of, and what they look like, helped us to see that;

- Nature and development of science 4: Science involves making predictions and describing patterns and relationships (ACSHE061)

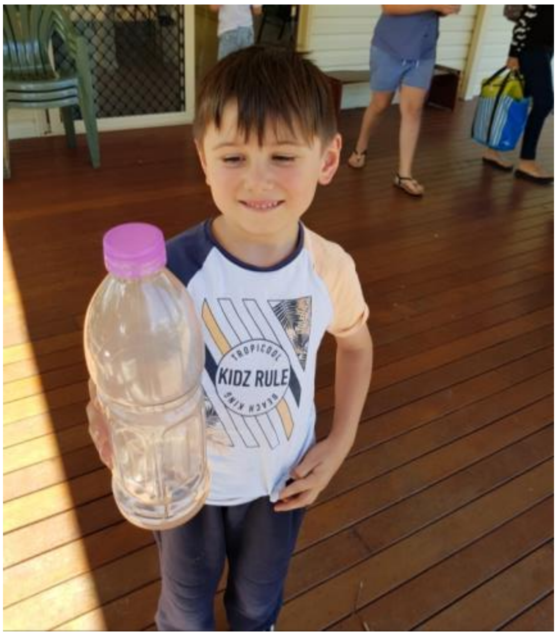
As we got to know the work of scientists such as Jacok Bjerknes we saw that;

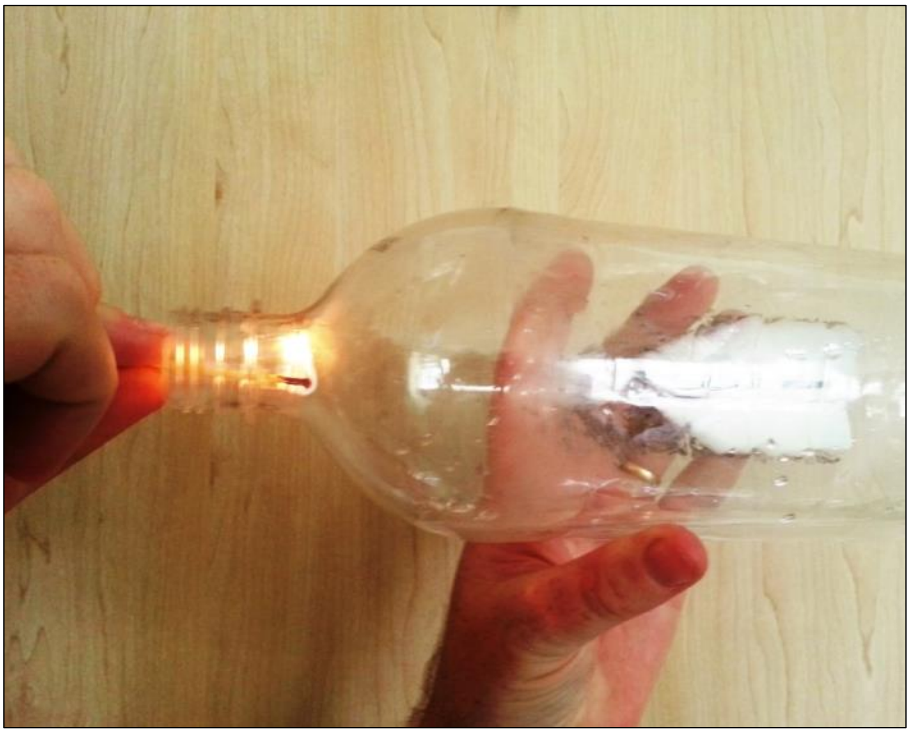
- Nature and development of science 6: Science involves testing predictions by gathering data and using evidence to develop explanations of events and phenomena and reflects historical and cultural contributions (ACSHE098)

Tips from the Masters



Squeeze tight, it can really pay off!





Quickly extinguish a lit match in order to make some ‘rain seeds’ from the smoke.

Appendix: Jacob and Wilhelm Bjerknes

Adapted 19 sep 18 from https://www.britannica.com/biography/Jacob-Bjerknes

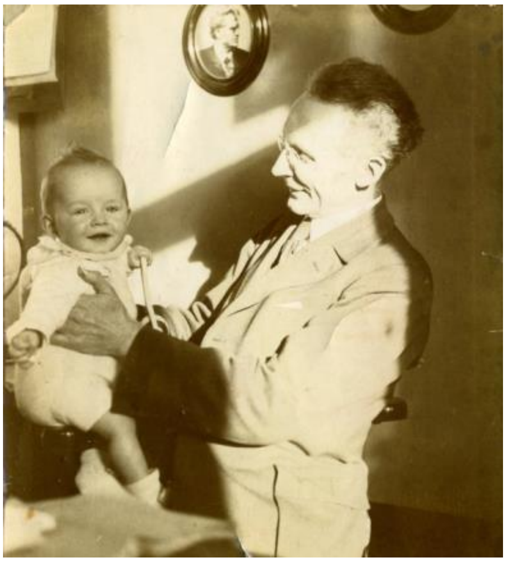
Wilhelm was Jacob's father, and they both loved maths and science – especially the science of the weather!

During world war two, the country where they lived was Norway, in the far north of Europe. Trying to remain neutral in the war they sold equipment and information to both sides of the battle.

One piece of information that was vital to any war effort is good weather prediction, but the theories of how the weather worked were only just beginning (and still have a long way to go!)

In around 1940 Jacob helped his father Wilhelm build a series of detection stations across the country to try and measure the weather. They found that the weather changes would sweep the county from one end to the other, rather than being isolated events that they partly expected. They named these changes 'fronts' after the battle fronts that divided the armies from each other during a war.

Their maths, and carefully research ideas, are still used today.



Baby Jacob on his father's knee – defiantly many years before their weather research! By Unknown - Bjerknes Family, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=55053439

A cute photo booth picture of David and his wife Hedvig

By Photo Booth, Tivoli, Denmark - Bjerknes Family, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=55052704

Appendix: High school maths

Taken 11 nov 2017 from http://hyperphysics.phy-astr.gsu.edu/hbase/Kinetic/relhum.html

Relative Humidity

The amount of water vapor in the air at any given time is usually less than that required to saturate the air. The relative humidity is the percent of saturation humidity, generally calculated in relation to saturated vapor density.

$$\mathit{Relative\ Humidity} = \frac{\mathit{actual\ vapor\ density}}{\mathit{saturation\ vapor\ density}}\,x100\%$$

The most common units for vapor density are gm/m^3. For example, if the actual vapor density is 10 g/m^3 at 20°C compared to the saturation vapor density at that temperature of 17.3 g/m^3 , then the relative humidity is

$$R.H. = \frac{10g\ /\ m^3}{17.3g\ /\ m^3}\,x100\% = 57.8\%$$

Calculation

Careful! There are dangers and possible misconceptions in these common statements about relative humidity.

Relative humidity is the amount of moisture in the air compared to what the air can "hold" at that temperature. When the air can't "hold" all the moisture, then it condenses as dew.

What's the problem?

Saturation vapor pressure | Dewpoint | Relative humidity calculation

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Saturated Vapor Pressure, Density for Water

Temp (°C)	Temp (°F)	Saturated Vapor Pressure (mmHg)	Saturated Vapor Density (gm/m³)	Temp (°C)	Temp (°F)	Saturated Vapor Pressure (mmHg)	Saturated Vapor Density (gm/m³)
-10	14	2.15	2.36	40	104	55.3	51.1
0	32	4.58	4.85	60	140	149.4	130.5
5	41	6.54	6.8	80	176	355.1	293.8
10	50	9.21	9.4	95	203	634	505
11	51.8	9.84	10.01	96	205	658	523
12	53.6	10.52	10.66	97	207	682	541
13	55.4	11.23	11.35	98	208	707	560
14	57.2	11.99	12.07	99	210	733	579
15	59	12.79	12.83	100	212	760	598
20	68	17.54	17.3	101	214	788	618
25	77	23.76	23	110	230	1074.6	...
30	86	31.8	30.4	120	248	1489	...
37	98.6	47.07	44	200	392	11659	7840

Below are some selected values of temperature and the saturated vapor pressures required to place the boiling point at those temperatures. The pressures are stated in mega-Pascals, where a Pascal is a Newton per square meter, and as a multiple of standard atmospheric pressure.

Temperature (°C)	Pressure (MPa)	Pressure (Atmospheres)
100	0.101325	1

150	0.4762	4.700
200	1.55	15.297
250	3.976	39.24
300	8.588	84.757
350	16.529	163.13
373.946	22.064	217.75

Graph for water | Saturated vapor pressure

PVT Surface

How much moisture can the air "hold"?

Careful! There are dangers and possible misconceptions in these common statements about relative humidity.

Relative humidity is the amount of moisture in the air compared to what the air can "hold" at that temperature. When the air can't "hold" all the moisture, then it condenses as dew.

Of all the statements about relative humidity that I have heard in everyday conversation, the above is probably the most common. It may represent understanding of the phenomenon, and has some common sense utility, but it may represent a complete misunderstanding of what is going on physically. The air doesn't "hold" water vapor in the sense of having some attractive force or capturing influence. Water molecules are actually lighter and higher speed than the nitrogen and oxygen molecules that make up the bulk of the air, and they certainly don't stick to them and are not in any sense held by them. If you examine the thermal energy of molecules in the air at a room temperature of 20°C, you find that the average speed of a water molecule in the air is over 600 m/s or over 1400 miles/hr! You are not going to "hold" that molecule!

Another possibly helpful perspective would be to consider the space between air molecules under normal atmospheric conditions. From knowledge of atomic masses and gas densities and the modeling of the mean free path of gas molecules, we can conclude that the separation between air molecules at atmospheric pressure and 20°C is about 10 times their diameter. They will typically travel on the order of 30 times that separation between collisions. So water molecules in the air have a lot of room to move about and

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are not "held" by the air molecules.

When one says that the air can "hold" a certain amount of water vapor, the fact that is being addressed is that a certain amount of water vapor can be resident in the air as a constituent of the air. The high speed water molecules act, to a good approximation, as particles of an ideal gas. At an atmospheric pressure of 760 mm Hg, you can express the amount of water in the air in terms of a partial pressure in mm Hg which represents the vapor pressure contributed by the water molecules. For example at 20°C, the saturation vapor pressure for water vapor is 17.54 mm Hg, so if the air is saturated with water vapor, the dominant atmospheric constituents nitrogen and oxygen are contributing most of the other 742 mm Hg of the atmospheric pressure.

But water vapor is a very different type of air constituent than oxygen and nitrogen. Oxygen and nitrogen are always gases at Earth temperatures, having boiling points of 90K and 77K respectively. Practically, they always act as ideal gases. But extraordinary water has a boiling point of 100°C= 373.15K and can exist in solid, liquid and gaseous phases on the Earth. It is essentially always in a process of dynamic exchange of molecules between these phases. In air at 20°C, if the vapor pressure has reached 17.54 mm Hg, then as many water molecules are entering the liquid phase as are escaping to the gas phase, so we say that the vapor is "saturated". It has nothing to do with the air "holding" the molecules, but common usage often suggests that. As the air approaches saturation, we say that we are approaching the "dewpoint". The water molecules are polarand will exhibit some net attractive force on each other and therefore begin to depart from ideal gas behavior. By collecting together and entering the liquid state they can form droplets in the atmosphere to make clouds, or near the surface to form fog, or on surfaces to form dew.

Another approach which might help clarify the point that air does not actually "hold" water is to note that the relative humidity really has nothing to do with the air molecules (i.e., N_2 and O_2). If a closed flask at 20°C had liquid water in it but no air at all, it would reach equilibrium at the saturated vapor pressure 17.54 mm Hg. At that point it would have a vapor density of 17.3 gm/m^3 of pure water vapor in the gas phase above the water surface. But if you had just removed the air and sealed the container with liquid water in it, you might have a situation where there was only 8.65 gm/m^3 resident in the gas phase at that particular moment. We would say that the relative humidity in the flask is 50% at that point because the resident water vapor density is half its saturation density. That is exactly the same thing we would say if the air were present - 8.65 gm/m^3 of water vapor in the air at 20°C represents 50% relative humidity. Under these conditions, water molecules would be evaporating from the surface into the gas phase faster than they would be entering the water surface, so the vapor pressure of the water vapor above the surface would be rising toward the saturation vapor pressure.

Relative humidity

R Nave

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Appendix: Posters – from our friends at Wikipedia.

Stratus clouds - making a blanket

Cumulous clouds - puffy, flat underneath

Cirrus clouds - wispy, made of ice

Nimbus clouds - any cloud that's raining