# THE IMPORTANT ROLE OF WATER AND WATER VAPOUR

## HOT TAKES

1. Water vapour and clouds affect the flow of heat energy into and out of the atmosphere; they dominate weather and climate.
2. However, their role in global climate remains one of the greatest sources of uncertainty. This may render climate models not fit for purpose.
3. If the models remain inadequate it is too soon to declare 'the science is in' on a 'climate emergency'.

**Almost 71% of the world's surface is ocean. Water evaporation from land and sea, followed by condensation as clouds, and precipitation as rain, dominates the world's weather and in turn climate. In fact, without a full understanding of water vapour and clouds, it is not possible to construct meaningful models of climate, and thus estimate human impacts.**

## The Important Role of Water & Water Vapour

Water is the only component of the atmosphere that can change from a gas to a liquid or a solid state, in the form of droplets or ice crystals in clouds, and back again.

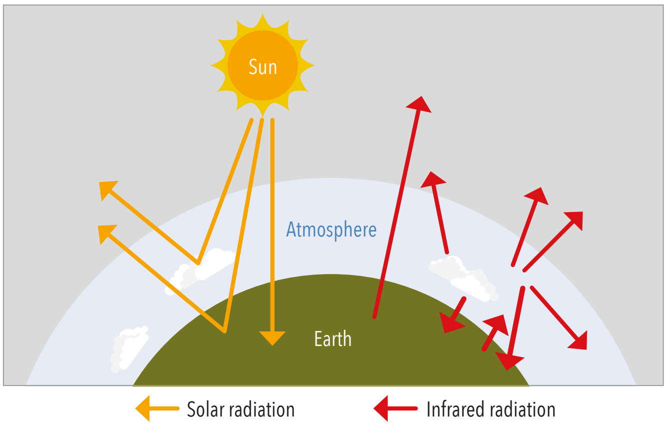
Water vapour is the dominant gas that keeps the Earth warm because of its 'greenhouse effect', see Figure 1. It is by far the strongest atmospheric absorber of the outgoing infrared radiation (IR) that continually leaves the Earth's surface.

As well as being the most abundant of all the greenhouse gases, water vapour's concentration changes widely with location. It can reach well over 40,000 ppm (over 4% of the atmosphere) in the tropics. This is 100 times greater than carbon dioxide ($CO_2$). It can still be more than 1,000 ppm at -20°C. Water vapour can also be more than 5,000 times greater than methane ($CH_4$), the next greenhouse gas after $CO_2$.

## The Important Role of Clouds

The response of clouds to future climate change is one of the greatest sources of uncertainty in climate models[1]. Clouds cover 65% to 70% of the Earth and have a major impact on the planetary energy budget. Low thick clouds have a *cooling effect* by acting as 'sun-shields', reflecting as much as 30% of incoming solar radiation back into space. But high thin clouds have a *warming effect* by reflecting IR leaving the Earth back to the surface.

**Figure 1:** The greenhouse effect[2]




Some of the infrared radiation emitted from the Earth's surface passes through the atmosphere, while some is absorbed and re-emitted back to the surface by greenhouse gases and clouds, making the Earth warmer than otherwise.

## Absorption of Short-wave Solar Radiation

Figure 2 shows the solar radiation transmitted by the atmosphere. $CH_4$ and nitrous oxide ($N_2O$) are virtually transparent to all incoming solar radiation. $CO_2$ only has two absorption peaks. One $CO_2$ peak overlaps with a big water vapour peak, competing with it. For incoming solar energy, water vapour is the dominant absorbing greenhouse gas, as shown by the notches in the yellow-red envelope.

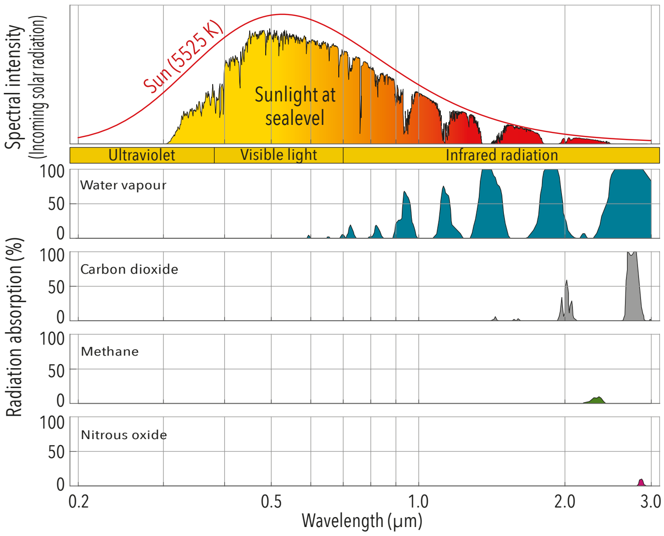
## Emission of Long-wave Infrared Radiation

Less than 60% of all solar radiation reaches the Earth's surface. Short-wave solar radiation reaching the surface, if not reflected, is absorbed and warms it. In response, both land and ocean surfaces then re-emit long-wavelength thermal IR (Figure 3). It is this radiation the greenhouse gases selectively absorb and re-radiate. Greenhouse gases partly choke off the transmission of IR through the atmosphere. Any increase in greenhouse gases creates a thermal imbalance that results in more heat being retained until the higher temperature results in the same amount of IR being radiated into space as before. This results in a warmer atmosphere, unless the extra heat gets removed via compensating pathways such as enhanced convection (Fact Sheet 12), or changes in cloudiness (Fact Sheet 13).

Water vapour dominates the greenhouse effect because of its wide absorption spectrum and far higher concentration. $CO_2$ makes a small contribution. $CH_4$ and $N_2O$ are almost inconsequential.

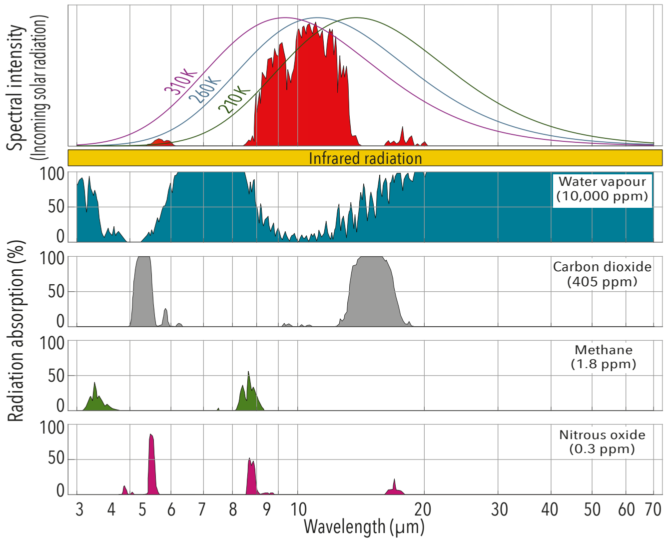
 

**Figure 2:** Absorption of incoming solar radiation[3]




Short wave solar radiation in the 0.2 to 3.0 micrometre wavelength range. The top panel shows the radiation from the Sun at the top of the atmosphere (smooth red curve) while the coloured envelope represents solar radiation transmitted through the atmosphere at sea level. The greenhouse gas absorption peaks (bottom panels) shape the absorption notches in the coloured envelope.

**Figure 3:** Figure 3: Emission of re-radiated thermal radiation[3]




Long-wave IR radiation (smooth curves) that would be re-emitted from Earth in the 3 to 70 micrometre wavelength range at different temperatures – if there were no greenhouse gases. The solid red envelope represents the IR 'spectral window' where IR not absorbed by greenhouse gases escapes to space. The combined spectra of the greenhouse gases (bottom panels) shape this spectral window.

## Water Vapour, Clouds, & Climate Models

The link between water vapour and clouds is extremely challenging to represent in mathematical models.

Water vapour can rapidly transform into clouds. Large changes in cloud coverage can occur quickly as a result of only very small temperature or humidity fluctuations (see Fact Sheet 13). These can happen rapidly over distances too short for climate models to accommodate. This makes it impossible to properly model the atmosphere accurately in a purely theoretical mathematical manner. Instead, overall parameters (or 'fiddle factors') have to be inserted to help the theoretical models tune out discrepancies between theory and observation[4].

But does this adjustment process, called *model tuning*[5], make models better simulators of reality, or only appear so?

Because climate models can't mathematically replicate the climate system from first principles, they are heavily dependent on how they are tuned. This practice can make *any* climate model fit the historic data used to calibrate it, so the need for tuning raises doubts as to how 'fit for purpose' they actually are[6]. Tuning can give an unfair impression of the models' actual forecasting skill and hence their ability to attribute climate change to increasing $CO_2$. It is more an art than science.

## Conclusion

If the models can't simulate nature, the slight effects of man-made $CO_2$ cannot be distinguished from the natural drivers of climate that are downplayed in the models. This greatly confounds attempts to discern human impacts from natural influences.



**SEE ALSO**

**FACT SHEET #12: TROPICAL CONVECTION: COOLING THE ATMOSPHERE**
**FACT SHEET #13: REFLECTIONS ON THE IRIS EFFECT**

Information in this fact sheet has been drawn from Climate Change: The Facts 2020 (IPA 2020), Chapter 11, by Dr Geoffrey Duffy. Fact Sheet series general editor: Dr Arthur Day

1. Boucher et al. 2013, *Clouds and Aerosols*: https://www.ipcc.ch/site/assets/uploads/2018/02/WG1AR5_Chapter07_FINAL.pdf.
2. Source: Sandra Anastasi.
3. Source: Adapted from: https://commons.wikimedia.org/wiki/File:Atmospheric_Transmission.png
4. Voosen, P 2016, 'Climate scientists open up their black boxes to scrutiny', *Science,* vol. 354, pp. 401–402.
5. Model tuning makes the model fit the hypothesis. See: Hourdin, et al. 2017, 'The Art and Science of Climate Model Tuning', *Bull. Amer. Meteor. Soc.*, vol. 98, pp. 589–602.
6. Curry, J 2017, 'Climate Models for the Layman', *The Global Warming Policy Foundation*, GWPF Briefing 24. https://www.thegwpf.org/content/uploads/2017/02/Curry-2017.pdf