Clouds and Water vapor

Water vapor as a greenhouse gas amplifier or stabilizer?

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Since the beginning of the discussion on greenhouse gases, it was clear to the scientists involved that water vapor is a much stronger „greenhouse gas" than CO_2, on the one hand because its proportion in the air is on average much higher (0.25% instead of 0.04%), and on the other hand because water vapor is active in a larger range of the infrared spectrum.
But because it is clear that it is politically hopeless to want to control the extremely complex water cycle, which has a decisive influence on all weather events, it was probably agreed to get the next effective greenhouse gas CO_2 under control. In addition, the countless phenomena in which water or water vapor are involved are by no means understood in their complex interaction.
Therefore, the IPCC has essentially agreed on the basic model that the CO_2 greenhouse effect is the primary „driving force" of climate change, and that water vapor strengthens or weakens this driving force as a result of „feedback effects".
The central point of contention between „climate alarmists" and „climate sceptics" is no longer the question of CO_2-sensitivity (3.7 W/qm or 1.1 degree C when doubling CO_2-content), but the question of feedback: „**Does the temperature increase by a multiple of the pure CO_2-sensitivity?**" in case of positive feedback or „**Does the total sensitivity remain lower than the pure CO_2-sensitivity?**" in case of more or less strong negative feedback.
This paper does not claim to model the complex relationships between temperature, water vapor and clouds in detail, as it

is partially done in the IPCC scenarios, but is limited to **finding a criterion based on measured and (easily) comprehensible dependencies by which it can be determined whether the total effect of all clouds and the total water vapor causes a positive or negative feedback.**

The known feedback factors

An obvious feedback factor is the absorption of more water vapor in the air slightly heated by CO_2 due to the Clausius-Clapeyron relationship. Since water vapor also acts as a greenhouse gas, this is considered a positive feedback relationship, even the most important feedback relationship of all.
If the water vapor content and thus condensation increases, then the adiabatic temperature gradient (MALR or SALR), the temperature decrease per altitude kilometer, decreases with the result that the radiation temperature increases at a given altitude and thus also the radiation power. This effect is called „lapse rate feedback" and represents a negative feedback. Its order of magnitude is about half of the positive water vapor feedback according to the models used. (p. 3355 in the linked document). The dilemma of these feedback calculations is that the actual calculations are located inside complex climate models that cannot be validated by outsiders.

Prof. Richard Lindzen has compared the current climate models regarding the feedback with measured satellite temperature data. The result of these complex calculations led him to the **conclusion that the total feedback must be negative** to be compatible with the measured data. **Thus the existing climate models** assume wrongly a positive total water vapor feedback.
In reality, the **effects of water vapor and cloud formation must produce a stabilizing, negative feedback in order that the climate models correctly reproduce the temperatures already measured**. However, the publication does not provide an explicit physical/meteorological mechanism that explains the

negative feedback or the nature of the problem in the models.

Uncertainty of temperature predictions due to errors of cloud feedback

Very recently Patrick Frank did a valuable analysis on the global temperature predictions of the currrent CMIP5 climate models with the title ***Propagation of Error and the Reliability of Global Air Temperature Projections***. The key findings of this analysis are:

- **A key weakness of all CMIP5 climate models is the annual average ±12.1% error in global annual average cloud fraction** produced within CMIP5 climate models
- **The errors are not random errors, but systematical**, giving a strong indication that there is a structural bias in the CMIP5 models.
- **This error is strongly pair-wise correlated across models, implying a source in deficient theory**.
- The resulting **long-wave cloud forcing (LWCF) error introduces an annual average ±4 Wm^{-2} uncertainty into the simulated tropospheric thermal energy flux**. This annual ±4 Wm^{-2} simulation **uncertainty is ±114 × larger than the annual average ~0.035 Wm^{-2} change in tropospheric thermal energy flux produced by increasing GHG forcing since 1979**.
- **Uncertainty in simulated tropospheric thermal energy flux imposes uncertainty on projected air temperature**. Propagation of LWCF thermal energy flux error through the historically relevant 1988 projections of GISS Model II scenarios A, B, and C, the IPCC SRES scenarios CCC, B1, A1B, and A2, and the RCP scenarios of the 2013 IPCC Fifth Assessment Report, uncovers a ±15 C uncertainty in air temperature at the end of a centennial-scale projection. The range of uncertainty is nearly 10 times more than the expected average 3.2 C temperature increase, and also much more than the worst case

scenario.

The unavoidable conclusion is that an anthropogenic air temperature signal cannot have been, nor presently can be, evidenced in climate observables.
As it can be expected, scientists convinced about the predicitions of the climate models questioned the author's Dr. Pat Frank conclusions, the one with the best arguments and fair behaviour was from Dr. Patrick Brown. This pIost contains also the arguments of Pat Frank's defense. The arguments are interesting but complicated.
It is fairly simple, however, to draw the following conclusion from this discussion: It is not questioned that the flux error from the cloud uncertainty is $4\frac{W}{m^2}$. Patrick Brown argues that this error might refer to a time period of 20 years, contrary to Pat Frank's interpretation that it refers to each year. If we accept – for the sake of the argument – Patrick Brown's position, then this error is still 10 times larger than the expected CO_2 greenhouse effect, which is $0.2\frac{W}{m^2}$ per decade. **Any possible Effect of CO_2 is buried in this large uncertainty, and therefore unpredictable, proving right Dr. Pat Frank's conclusions qualitatively.**

Again we have a negative diagnosis: The climate models get the cloud formation process wrong. We still have to find a plausible mechanism that makes sense and that could be a conceptual foundation for the improvement of models. The following considerations do not claim to exactly model the cloud feedback – ako improved „plugin" for climate models –, but **the purpose of the investigation is restricted to the simplified question whether globally water vapor and clouds together will provide a positive or negative feedback to the assumed CO_2-forcing.** That **the relations between water vapor and clouds are very complicated and are not adequately represented in the current climate models**, is made transparent in this **speech by Dr. Roy Spencer**:

Feedback of the clouds inside the troposphere

Due to the manifold manifestations and the unpredictable constellations of clouds, it is difficult to simulate these within climate models. In addition, the „elementary cells“ of the climate models with a side length of 100 km are too coarse to correctly model the dynamic events of cloud formation. As reported above this has led to the clouds appearing in the climate models in an incomplete and therefore biased way.

An extremely important property of clouds for the estimation of climate-relevant effects is that they influence both the incoming short-wave radiation via albedo and the outgoing heat radiation via infrared absorption. The strength of these two influences is considerable and is made apparent by the fact that we can feel both of them immediately:

- When we stand in the bright sun and a cloud moves in between, we immediately feel a distinct cooling, i.e. reduction of the short-wave radiation.
- On a starry night it is significantly colder than on a night with a cloudy sky, i.e. the heat escapes faster into space when there are no clouds. This effect is mainly caused by the fact that the clouds prevent direct radiation from the earth’s surface through the „atmospheric window“.

To capture these simple phenomena adequately and to weigh them correctly statistically is not trivial. The albedo of the atmosphere for incoming light can be recorded with satellites.

NASA’s two Earth observation satellites CloudSat and CALIPSO have more accurately determined the global cooling **Albedo effect of the clouds** over the period 2000 to 2010. It **was on average 47.5 W/m^2 and is mainly caused by the reflection of (short wave) sunlight by clouds in the mid-latitudes of the respective summer hemisphere.**
The estimated warming **effect due to water vapor and clouds is**

about 24-31 W/m², in IPCC report AR5 a mean value of 30 W/m² is assumed.

In the balance, this results in an increased net outgoing emission compared to the hypothetical situiation with no water vapor and clouds, i.e. a total negative forcing of 16.5-23.5 W/m². These overall values include all cloud types, the cumulus clouds with large albedo as well as the cirrus clouds with almost disappearing albedo.

Thus the total static effect of water vapor and clouds is negative, i.e. cooling, on a worldwide average and calculated over all cloud types. This is consensus in climate science.

Nevertheless, the usual climate models arrive at positive water vapor feedback and a total sensitivity of 2-5 degrees Celsius (See above for the explanation). However, a positive water vapor feedback is not possible due to the following simple considerations:

- With the doubling of CO_2 a temperature increase of 1 degree C is assumed. Regarding the relation between temperature and water vapor there may be two cases: Either there is no increase of water vapor when temperature increases (in extremely dry areas). Then naturally there is no feedback at all. At most the atmosphere can absorb 7% more water vapor per degree C temperature increase. This happens mainly over the oceans or in tropical rain forests. This is a strictly positive correlation with causal interpretation.
- It can be observed that the large scale cloud formation correlates positively with the water vapor content of the atmosphere. More precisely, the most humid – equatorial – areas are also the areas with the maximum cloud formation, but there are also areas of extremely large cloud formation, e.g. in the southern Pacific, although the humidity is lower.
- To sum up, **a corresponding increase in cloud formation**

is to be expected with a global temperature increase.

- If there were no water vapor and no clouds at all, the forcing would be exactly 0, and the greenhouse effect would be determined by CO_2 alone. Due to the positive correlation between temperature and cloud formation and the dominance of global negative cloud albedo feedback over global positive water vapor and cloud feedback, **there must be always a negative overall feedback**.
- **There is no justification for the assumption in IPCC models that – globally seen – the ratio of negative albedo forcing to positive water vapor forcing would be reversed with increasing water vapor content**. The incorrect positive forcing can be explained by the common systematic error in cloud albedo calculations in the climate models, as discussed above . Therefore the function between water vapor content and water vapor/cloud forcing is globally monotonously decreasing, with the result of an overall negative feedback for additional water vapor.

**The clouds thus have a strongly stabilizing effect: Global warming leads to additional global cloud formation due to the higher water vapor content, and thus to the negative feedback described above, which ultimately has a cooling effect.
Versely, a global cooling via the reduced water vapor impedes cloud formation, the warming influence of sunlight can have a stronger effect.**

The impact of this insight on the climate debate cannot be overestimated. **From the negative feedback of water vapor and clouds it follows that there can be no temperature increase above the pure CO_2 value of 1.1 degrees C when doubling the CO_2 value**.