

# Impacts of Hydroxyl Dispersal on Aerosol and Handling the Global Dimming Paradox

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## Abstract

The rebound warming shock from halting 30% of aerosols is causing some warming in July 2020 due to the ongoing societal shutdown of combustion activities. It is advancing all major tipping points and feed backs, and it is time to prepare additional action which can counter the aerosol rebound along with as many other issues as possible. Papers cited here estimate up to a 1°C global dimming-cooling effect. To counter this rebound of up to 1°C with hydroxyl dispersal, an equivalent and rapid release of hydroxyl from ground that offsets 71.4% of the 150ppm CO<sub>2e</sub> excess, which is 107.1 ppm, amounting to a suggested 114 MT of OH, via a 57MT release of oxide gas.

Global dimming is partially caused by reduced aerosol aging due to lowered background OH\* (hydroxyl) which makes aerosols hygroscopic and rain out more readily. Lowering the aerosol residence time this way includes increasing the albedo of aerosol which leads to cooling. Lowered hydroxyl leads to an overall increase in warming as less GHG is removed. A 30% increase in OH\*, should equate to a 30% brightening of aerosols, and equivalent TAC (total atmospheric constituent) decrease, which allows outgoing radiation to exit.

## Discussion

Increased OH\* will increase precipitation cycling when also aging aerosols. This means that the heat given off during the condensation-precipitation phase change at the cloud deck is increased. As aerosol aging increases, droplet size due to aging decreases, which increases precipitation yield which enhances mineralization of CO<sub>2</sub> by buffering. More rain out of oxidized N<sub>2</sub>O, CH<sub>4</sub> products, Nox, PFC-CFC-HFC, SLCPs occurs.

Hydrogen in the OH\* protrudes when attached to aerosol particles, which readily penetrates water droplets. This increased coalescence between aerosol and water creates droplet growth, which leads to fast collection rates. A 30% or more increase in OH\* a same magnitude increase in its precipitation cycling mechanics enhancement because it is a relatively linear process once other reaction losses by apportionment are calculated. It is dose-dependent.

Warming over oceans increases biogenic aerosols, but already overwhelmed background OH\* levels means these aerosols take longer to age, reflect sunlight, and coalesce. This general condition is found to be increasing globally alongside TAC (total air constituent) forcings which desertify air sheds, despite increased atmospheric water vapour. These are some of the processes covered by the term “indirect effects” of aerosols, which do also include “indirect effects” from the aggregate loading of TAC.

The only compound that can address across-the-board and systemic imbalances by being increased, without toxic residues, is hydroxyl. It also removes all GHGs, which must be done in order to address any aerosol dimming-brightening rebound effects.

Table 1. The OH\* System Characteristic Linkages Intensity

		Estimated Rxn/process Coupling
↓↑	TACs-Total atmospheric constituents ↓[OH*]↑heating. Reduction=direct and indirect global cooling	10000+, (100%), Total Habitat disruption factor
↑	CAP(criteria air pollutants)↓[OH*] for other reactions	80
↑	GHGs and SGHG ↓[OH*] for other reactions	80
↑	Aerosols ↓[OH*] for other reactions-precipitation & albedo	4
↑	VOCs ↓[OH*] for other reactions -precipitation & albedo	3
↑	SLCPs ↓[OH*] for other reactions - ↓ heat transfer	3
↑	BC and brown carbon- ↓[OH*] for other reactions -precipitation & albedo	5

↓↑	H2O Vapour ↓↑[OH*], drought, deserts, indirect forcing, precipitation, albedo, heat transfer, species deposition, buffering, dimming, warming	3333, 30% OH* formation partner
↓↑	Solar insolation UVB, ↓↑[OH*]	3333, 30% OH* formation partner
↑	SRM Geoengineering, ↓[OH*] via ↓UVB & attachment	4
↓	Ozone photolysis/breakdown: ↓↑[OH*], O <sub>3</sub> -> O <sub>2</sub> +O-> 2OH*	1666.5, 15% OH* formation partner
↑	Ocean heating, ↑aerosols, ↓[OH*] .↑[OH*] via ↑convection, evaporation, CH <sub>4</sub> H <sub>2</sub> O	2333, OH* precursor
↑	Land based heating, ↑[CH <sub>4</sub> ], ↓[OH*],↑[CO <sub>2</sub> ], ↑[CO <sub>3</sub> ] <sup>-2</sup> , fires, floods, drought, desertification, extinction events, famines, pandemics, convection	700, OH* precursor system
↑	Isoprene, ↓[OH*]	2
↑	↑anthropogenic [CO <sub>2</sub> ], runaway heating, CAP overloading, forcing, fires, floods, drought, desertification, extinction events, famines, pandemics, convection, active direct removal required.	800, Total Habitat disruption factor
↑	↑[OH*] via intervening dispersal over 50-100 years, or equivalent removal via several other single GHG removal technologies.	10000+, (100%), <50%=failure
↓↑	Human behaviour, reduction, mitigation, intervention, ↓↑[OH*] system. Root cause is lack of GHG removal.	10000+, (100%), <50%=failure,

For the most part, a direct projection of OH\* needed can be done. For CAP and GHG apportionment, the following type of table will provide a total.

Simple Calculator of *OH Needs	
Airshed Constituents in ppm	
CAP	ppm
CO	0.871
Sox	0.0004
CH <sub>4</sub>	1.867
PM 2.5	0.0246
O <sub>3</sub>	0.0246
Nox	0.0155 .010-.045
CO <sub>2</sub> 0>0006x 410ppm	0.42 .01% of 420ppm buffered by *OH in H <sub>2</sub> O
VOC	0.0593
SGHG basket	0.018638 synthetic GHGs or CFC gases
<b>Total Reactant Flux</b>	<b>3.301038</b>
(*)OH ppm over an hour	
PPB-PPM (*)OH natura	0.0108 0.006*1800seconds per 3600 s)
added PPM (*)OH	0 1.1 , 2.2, 1.5,3
.25 assist	0.0027 25% builds up in air
<b>Total Flux 24 hour</b>	<b>0.0135 sample every 2 seconds</b>
	24 H
<b>DEFICIT OF OH</b>	<b>3.287538 PPM per 24 H.</b>
OH produced in 24 H	0.5184 based on steady state, 2 s extinction
<b>24 hour OH deficit</b>	<b>2.639538</b>

Table 2. Taken from a spreadsheet designed to assess all TACs in ppm units, so that OH\* deficits can be accounted for. The 24 hour cycle of levels is used because of the diurnal cycle of OH\* production, and the overnight recycling of 25% for the next day.

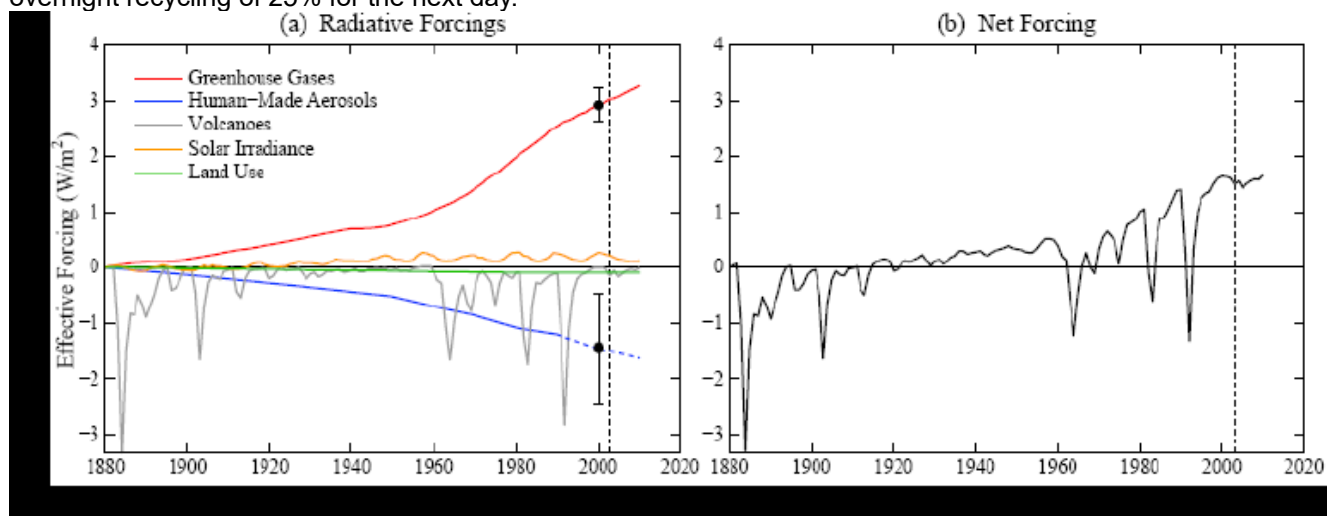
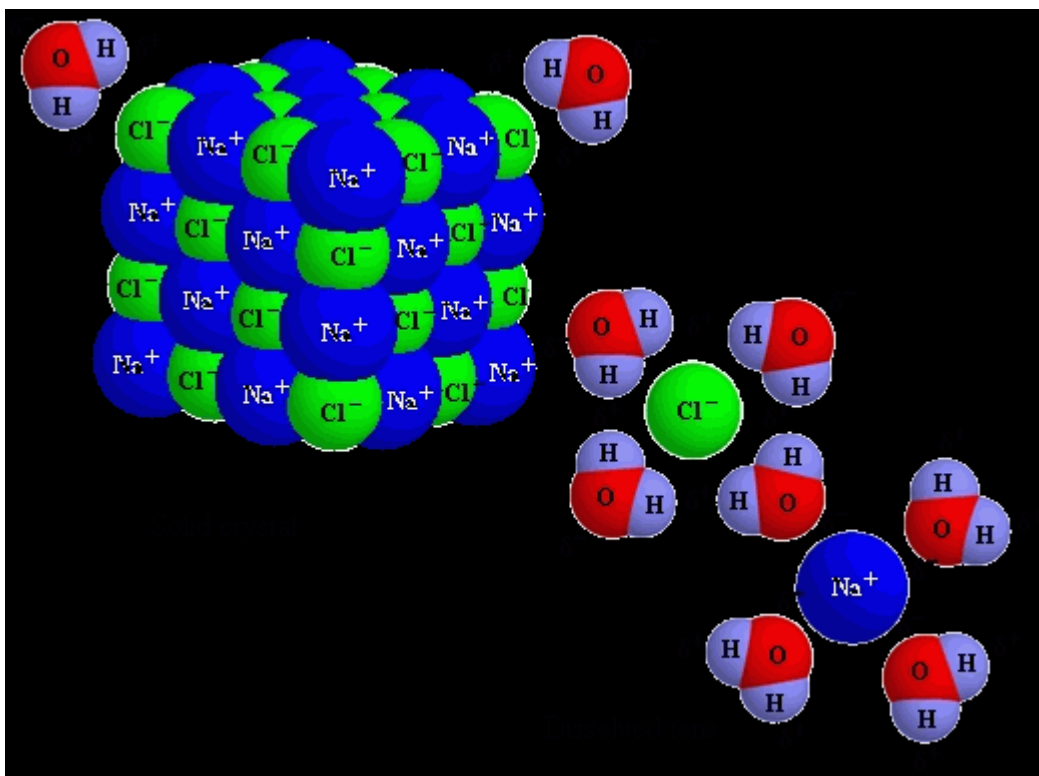


Fig 1. Used by Hansen et al. (2007), except the tropospheric aerosol forcing after 1990 used by Hansen et al. (2007), except the tropospheric aerosol forcing after 1990 is approximated as -0.5 times the GHG forcing. Aerosol forcing includes all aerosol effects, including indirect effects on clouds and snow albedo. GHGs include O3 and stratospheric H2O, in addition to well-mixed GHGs. These data are available at <http://www.columbia.edu/~mhs119/EnergyImbalance/Imbalance.Fig01.txt>

### Ref 3 and discussion of Marine Cloud Brightening

sodium chloride, or NaCl, is a strong electrolyte, which means it completely dissociates into sodium cations, Na<sup>+</sup>, and chloride anions, Cl<sup>-</sup>, when placed in water. It turns out that the strong interactions between the sodium cations and the partial negative oxygen, and the chloride anions and the partial positive hydrogens, although they disrupt part of the hydrogen bonding that takes place between water molecules, actually *strengthen* the surface tension of water.

In other words, you get some ionic component to the overall hydrogen bond-dominated interactions from the addition of these cations and anions.



Note the geometry change of the water around the  $\text{Na}^+$  ion, the hydrogen now is oriented away from it, this sets up polar bonding with the O in the water molecules surrounding the  $\text{Cl}^-$  ion, generally making things “tighter together” by ionic attraction as a higher surface tension. For droplets, the relative effect would be notable. The bonding would lower background  $\text{OH}^*$  hydrogen ligand ability to penetrate water with charge-balanced ions is present in this way.

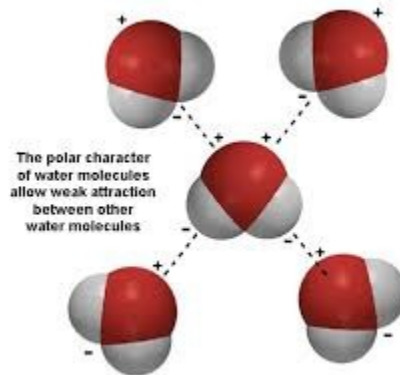


Figure 3. Fresh water structure tendency.

The premise of the Cloud brightening project: “The idea behind the marine cloud brightening (MCB) geoengineering technique is that seeding marine stratocumulus clouds with copious quantities of roughly monodisperse sub-micrometre seawater particles could significantly enhance the cloud droplet number concentration thus increasing the cloud albedo and longevity – thereby producing a cooling, which computations suggest could be adequate to balance the warming associated with a doubling of atmospheric carbon dioxide.”

The two-function premise of this work stands in contrast to  $\text{OH}$  dispersal in several ways: cost, rebound warming issues, it leaves GHGs untreated, is geographically more limited.  $\text{OH}$  dispersal enhances the albedo of organic aerosols, treats the root causes of warming directly, and sponsors more cloud cycling of colder precipitation events that lead to cleaner convection events and thus brighter clouds with +n over time. The comparison should stop there for this discussion.

#### Aerosol Effects <sup>5</sup>

Where aerosols act as cloud condensation nuclei (CCN), the larger the number of CCN, the higher the resulting cloud albedo (first indirect effect) and the lower the precipitation efficiency (second indirect effect, sometimes called “cloud lifetime effect”).<sup>5</sup>

**Table 1.** Global Mean AOD, Absorption AOD, Sulfate AOD, Surface Air Temperature, Precipitation, and Aerosol RFP

	1860 <sup>a</sup>	2000 <sup>b</sup>	2010 <sup>c,f</sup>			2100 <sup>d,f</sup>		
			RCP4.5	RCP4.5	RCP4.5	RCP4.5	RCP4.5**	RCP4.5**
AOD	0.1015	0.1440	0.1572	0.1222	0.1626			
Absorption AOD	0.0043	0.0072	0.0079	0.0059	0.0084			
Sulfate AOD	0.0215	0.0556	0.0657	0.0367	0.0688			
Surface air temperature (K) <sup>g</sup>	286.9	285.9	287.5	289.7	288.8			
Precipitation (mm day <sup>-1</sup> )	3.03	2.95	3.02	3.17	3.08			
Aerosol RFP (W m <sup>-2</sup> ) <sup>h</sup>	N/A	-1.78 (-2.9)	-1.75 (-2.9)		-0.49 (-0.9)			
Sulfate RFP (W m <sup>-2</sup> ) <sup>h</sup>	N/A	-1.74 (-2.1)	-1.66 (-2.1)		-0.61 (-0.6)			
BC RFP (W m <sup>-2</sup> ) <sup>h</sup>	N/A	+0.13 (-0.5)	+0.03 (-0.6)		-0.02 (-0.2)			
OC RFP (W m <sup>-2</sup> ) <sup>h</sup>	N/A	-0.38 (-0.4)	-0.27 (-0.4)		-0.02 (-0.0)			

<sup>a</sup>Mean values for years 1–200 of the 1860 control simulation of CM3.

<sup>b</sup>Mean values for years 1996–2005 for the three-member ensemble of CM3 simulations with time-varying aerosol and aerosol precursor emissions (all other forcings held at 1860 values). Note that these values differ from those that would be obtained from CM3 simulations including time variation of all forcing agents.

<sup>c</sup>Mean values for years 2006–2015 for the three-member ensemble of CM3 simulations forced by RCP4.5 (for all forcing agents).

<sup>d</sup>Mean values for years 2091–2100 for the three-member ensemble of CM3 simulations forced by RCP4.5 (for all forcing agents).

<sup>e</sup>Mean values for years 2091–2100 for the three-member ensemble of CM3 simulations forced by RCP4.5\*\* (with aerosol and aerosol precursors held at year 2005 values, but all other forcing agents following RCP4.5).

<sup>f</sup>Note that the RCP4.5/RCP4.5\*\* simulations are initialized in year 2006 from the end of historical simulations, including time variation of all forcing agents, and thus have a different present-day state from the historical aerosol-only simulations.

<sup>g</sup>Global mean surface air temperatures have been adjusted by subtracting the long-term drift (0.001 °C a<sup>-1</sup>) in the 1860 control simulation of CM3.

<sup>h</sup>RFP is calculated as the net radiative flux change at the top of the atmosphere in prescribed SST simulations with time-varying versus 1860 aerosol and aerosol precursor emissions, as described in sections 3.1–3.2. Values in parentheses are RFP at the surface.

We can see from this table the RFP, the radiative flux change at the top of the atmosphere due to each parameter and surface Wm<sup>2</sup> in parentheses. It agrees in scale to other literature cited, and the net aerosol masking effect is found in lines 7 and 8 for representative concentration pathway 4.5. There is a negative radiation change at the top of the atmosphere—and the bottom for both readings so this shows the “dimming” effect. When lines 7–9 are added, you see a 3.1Wm<sup>2</sup> cooling at the surface in 2010, and 0.8Wm<sup>2</sup> cooling in 2100 where the CO<sub>2</sub> is at 570ppm, so that particular heat forcing is a factor compared to 2010.<sup>5</sup>

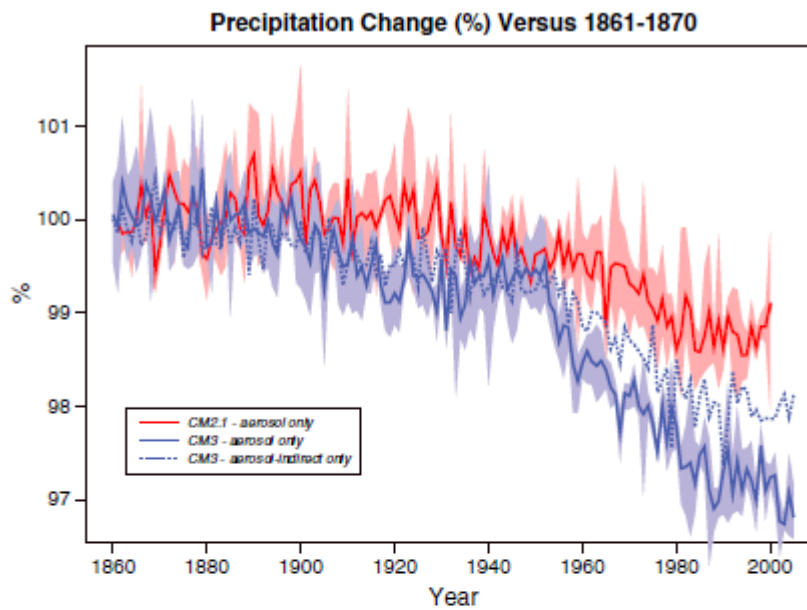
## Global Anomalies which Increased OH\* Can Address

In the cited papers, we note that the models demonstrate the precipitation change caused by aerosols globally and it trends downward, and so less rain, while viewing the next 3 graphs<sup>5,6,7</sup>, secondly OH\* level increases, and thirdly, the global water vapor trend increases (The resulting Zugspitze time series including the years 1996–2008 comprises IWW retrievals from a number of 5815 individual spectra as displayed in Fig. 5:

OH\* is expected to trend upwards as water vapour does. The first graph again shows an aerosol caused decrease in precipitation—the “indirect effect”, despite an increasing background water vapour/hydroxyl primarily because hydroxyl attaches to the aerosol instead of oxidizing other constituents like VOCs, (into CCN), GHGs and buffers CO<sub>2</sub> at a proportionate rate, so the aerosols and loading are causing a decrease in the OH\* contribution to CCN coalescence with droplets. OH\* levels have just moved into being swamped when pitted against all of the various atmospheric constituents pulsed into the atmosphere.<sup>9</sup> We readily see this with CH<sub>4</sub> removal- OH\* is not keeping up by lowering levels any more, even though there is more OH\* formed from water vapour.

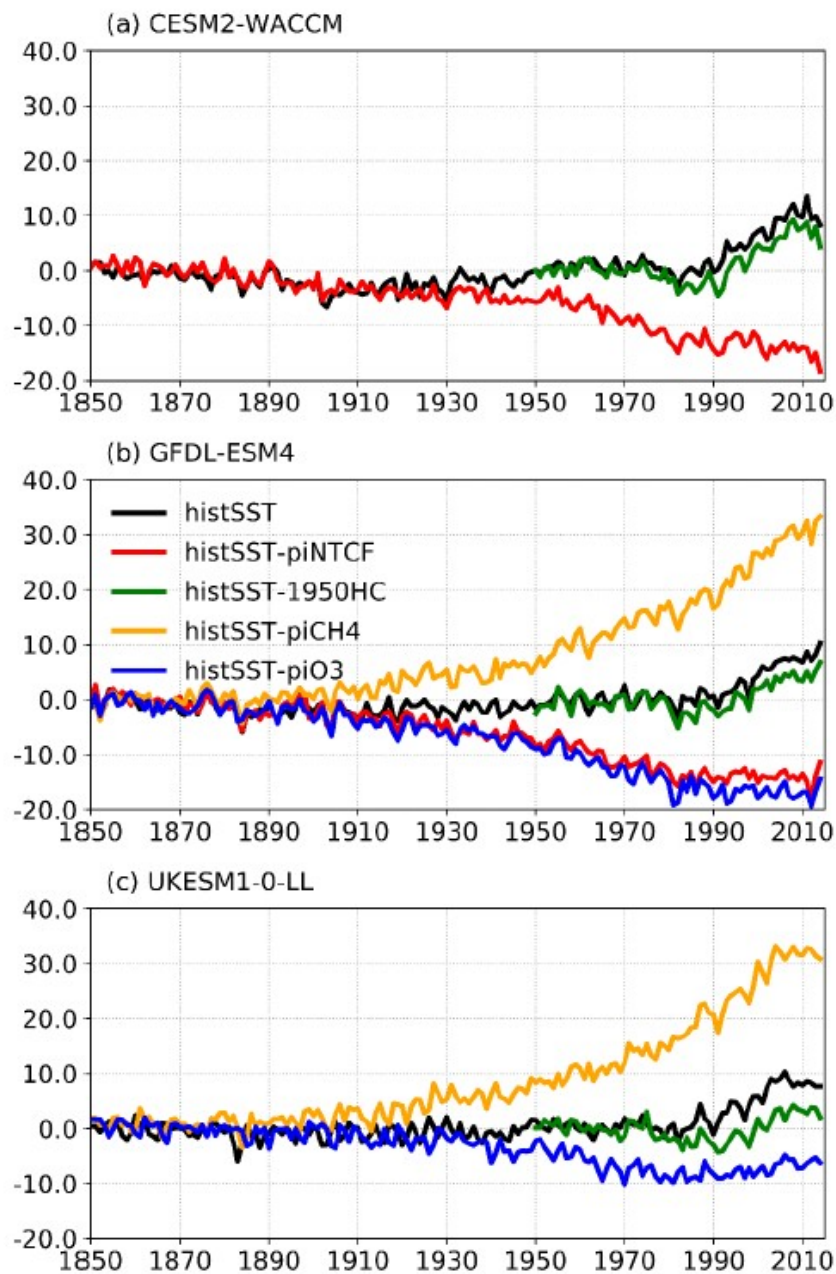
The sudden removal of aerosols such as in COVID 2020 is going to reduce the precipitation loss it caused. More OH will be available to enhance CCN aging, and thus, increase albedo, cycling of coalescence, precipitation and phase change cooling, and convective systems. There are thermal resolutions found with optimal and even high levels of OH\* as listed in the below table. Let’s then look at convection.

Figure 4.



**Figure 3.** Global mean percentage precipitation change relative to (1861–1870) average simulated by CM2.1 (red shading for three-member ensemble envelope and red line for ensemble mean) and CM3 (blue shading for three-member ensemble envelope, blue line for ensemble mean, blue dashed line for three-member mean when only forced by aerosol indirect effects). Both models are forced by changing levels of sulfate, BC, and OC aerosols (emissions for CM3, concentrations for CM2.1), whereas all other forcing agents, natural and anthropogenic, are held fixed at 1860 (or 1861 for CM2.1) values. In the case of CM2.1, natural aerosol concentrations (dust, sea salt) are held constant, whereas in CM3 their emissions are calculated interactively. See text for details.

Figure 5.



522

523 **Figure 5** Tropospheric OH anomaly (%) for sensitivity experiments from (a) CESM2-WACCM, (b) GFDL-ESM4 and  
524 (c) UKESM1. Note the values are expressed as a percentage anomaly relative to the 1850-1859 mean value in the  
525 histSST run in each model.

Figure 6.

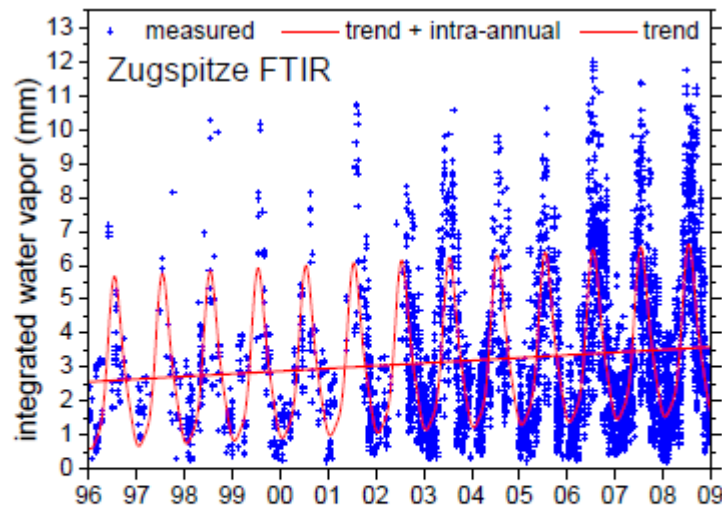


Fig. 5. Time series of Zugspitze (47.4° N, 11.0° E, 2964 m.a.s.l) FTIR IWV retrievals from individual measurements (15–20 min integration) matched to radiosonde characteristics. See Table 3 for the trend analysis results.

Table 3.

Table 3. Existence and significance of IWV trends derived from harmonized FTIR measurements at the Zugspitze and Jungfraujoch via bootstrap resampling.

	trend (mm/decade)	uncertainty interval [2.5th percentile, 97.5th percentile] <sup>a</sup> (mm/decade)	significant non-zero trend? (95 % confidence)
Zugspitze [1996–2008]	0.79	[0.65, 0.92]	yes
Zugspitze [1996–2002]	0.63	[0.20, 1.06]	yes
Zugspitze [2003–2008]	1.41	[1.14, 1.69]	yes
Jungfraujoch [1996–2008]	0.08	[−0.01, 0.17]	no
Jungfraujoch [1996–2002]	−0.04	[−0.27, 0.19]	no
Jungfraujoch [2003–2008]	0.05	[−0.18, 0.28]	no
Jungfraujoch [1988–2008]	0.04	[−0.01, 0.10]	no

<sup>a</sup> Underlying uncertainty distributions constructed via 5000 bootstrap resamplings for each trend.

### Convection’s Meteorological and Climate Functions

Convection – Heat transfer through the movement of a liquid or gas. That is, the liquid or gas of a certain temperature moves to a new area, thus changing the temperature of the new area. This is the phase change based heat transfer we find deeply important for the Earth’s energy balance.

In an effort to achieve equilibrium, air is constantly moving around the atmosphere. This movement gives us our convective heat transfer, and as we mentioned earlier there are two types.



1. Convection – When warm, moist air near the surface rises to be above the heavier cool, dry air this is a form of heat transfer or convection. The rising motion typically cools the air. As the air cools, it reaches the dew point and all of the moisture in the air condenses– forming clouds. Depending on many factors, these clouds can form rain and even storms.

2. Dry Convection –The type of convection not associated with storms is called dry convection. This occurs when warm air at the surface rises to be above the cooler air overhead. Because there is no moisture, this typically doesn't have cloud cover associated with it.

There are several laws involved, but to keep it simple we'll just say convection isn't just the movement of warm air. It also includes the cold air sinking. Because if the warm air goes up, something needs to take its place. So the cold air sinks to the surface. In the second image, we see this regular trend of cold dry air sinking, and warm moist air rising. Figure 7.

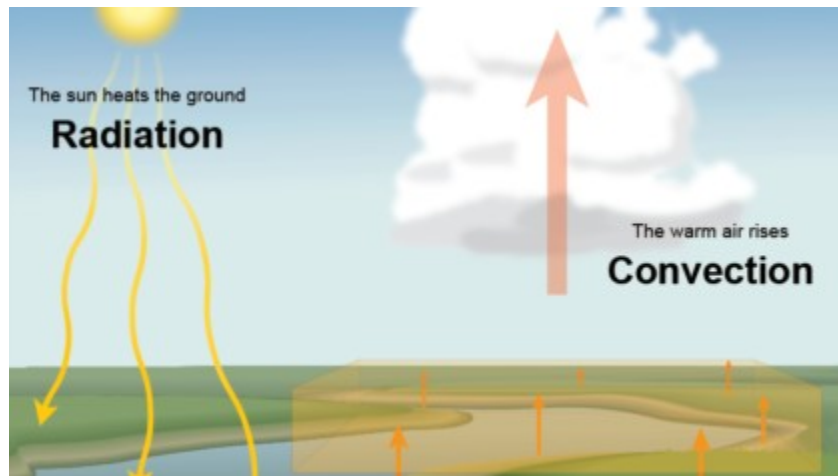
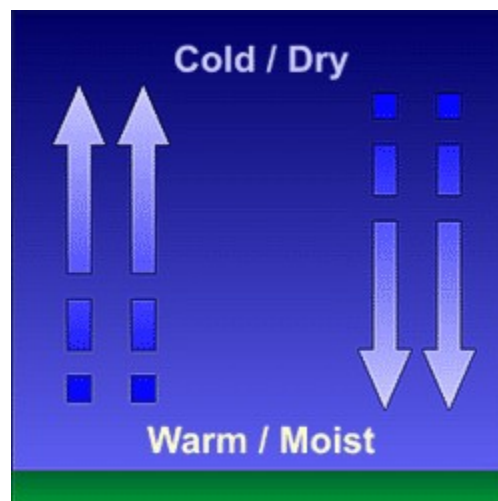


Figure 8.



This normally reliable trend, coupled with sunlight's UVB rays hitting the H<sub>2</sub>O in the fresh convection parcel, sets up new air that can oxidize aerosols, turning them into brighter, more reflective CCN that will coalesce into rain droplets. Heat waves are shunted upwards to the cloud decks, and, as the vapour condenses, they travel farther upwards, causing cooling. The heat needs to continue outwards to space, but then GHGs interfere by trapping it and causing an imbalance. However, fresh hydroxyl is quickly formed, and is oxidizing some of the GHGs, just no longer enough to maintain the balance it once did due to excess levels. When the altitude is high enough and the gases thin out, heat waves readily get out to space. This thin area keeps getting higher up however, so-down-welling of the coolness, and up welling of the heat waves is impaired.

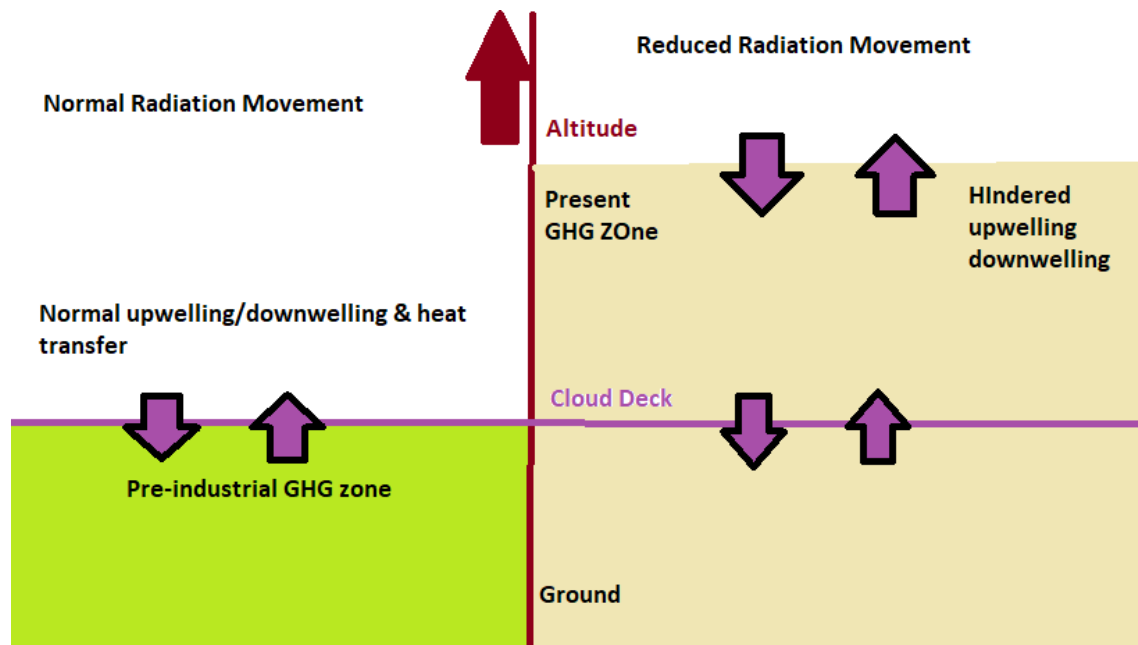


Figure 9. Change in atmospheric radiative transfer because of GHGs.

## Marine Cloud Brightening Discussion

This is essentially a microscopic mass-adding technique that will create steric hindrance to precipitation chemophysics. Droplet coalescence is hindered because the salt molecule is large, and cannot aid in the surface tension penetration of gathering droplets like the H ligand found on the OH\*. The two steps-coalescence, and precipitation are retarded, increasing cloud albedo and lifetime. This measure does not address the root cause of global heating, but is serving as a simple short-term emergency cooling strategy like other SRM techniques.

OH\* increases the albedo of aerosols, which probably is a near equivalent albedo measure if considered globally and for a regional dispersal..

## Black Carbon And Hydroxyl Comment

We have viewed (2007) hydroxyl turning white paper black, rather than what peroxide, H<sub>2</sub>O<sub>2</sub> does-bleach it. This we believe is a strong property of hydroxyl. A lot of carbonaceous material in the atmosphere likely turns black, and thus may have a significant impact on warming-some of the unattributed warming found in models may be this phenomenon. Glaciers graphically demonstrate this black soot, which is probably serving as a black body radiator when aloft. When OH\* is effectively swamped, however, the reaction:  $C + OH^* \rightarrow CO + H$ ,  $CO + OH^* \rightarrow CO_2$  is more limited, especially in the presence of water vapour. This may lead to more fine BC. More BC in clouds decreases albedo and increases droplet size once aerosol and droplets are coupling. The cp of BC is higher which can increase cloud temperature, and decrease coalescence. If OH\* is swamped or lowered, the precipitation mechanics are hindered. C<sub>2</sub> and larger particles are probably very involved in black carbon levels. It is likely that a BC created from a brown carbon, or VOCs, gets a hydroxyl ligand with an H atom protruding while being blackened, thus helping the particle coalesce with droplets, and be rained out.

This clearly limits the scope of the BC to the four independent climate-relevant variables: i) particle light scattering coefficient, ii) particle light absorption coefficient, iii) particle number 255 concentration, and iv) particle number size distribution.<sup>2</sup> Carbonaceous particles coloration to black as a chemical property of OH\* may cause a wholesale increase to ii), particle light absorption coefficient, and may be quantifiable with OH\* exposure testing in the lab.

## Conclusion

We see the many couplings found with OH\* in the table provided, which safely can be described as the total, residue-free atmospheric constituent removal system for the planet for over 2.4 billion years. It is now overwhelmed, which puts life on Earth in jeopardy from the GHG based overheating which must be reversed, not just slowed<sup>11</sup>. If concentrated streams in MT of hydroxyl are emitted to treat GW, it is likely that the rebound warming penalty caused by aerosol removal can be avoided if the dispersal is large.

Lower down, with cloud cycling, down welling-up welling are still needed, and removing the baseline tendency for precipitation with artificial marine cloud brightening, SRM particles, and anthropogenic pollutants means reducing upward heat transfer while blocking incoming solar radiation.<sup>8</sup>

The TAC load can be seen as a climate and habitat security problem which blocks outgoing radiation dangerously, and with hydroxyl, can be addressed in a holistic way by increasing its levels through releasing concentrated streams at 50m height and above. When the pH of the stream is higher than 10.3, CO<sub>2</sub> removal occurs through scavenging and CO<sub>3</sub> formation, which is rained out. All other reactants near the concentrated stream are removed as they contact the OH\* plume. Cleaning large air parcels of their TAC load reduces the air parcel's climate sensitivity, which translates into better heat transfer properties.

The OH\* system is out of balance because of TAC overloading, which we may be forced to address by deploying a wholesale TAC removal process. One-greenhouse-gas-at-a-time treatment technologies and options offer a more limited scope by comparison, and have relatively heavy engineering/resource costs. These are discussed elsewhere, but include, unwanted chemical residue streams and side reactions, inefficient whole atmosphere-sucking equipment, and primarily target only one GHG, such as CO<sub>2</sub>, or CH<sub>4</sub>.

The OH\* dispersal technology available uses ordinary air to make concentrated hydroxyl streams by using 1/55,000.000th the volume of the atmosphere, and allowing diffusion, weather and air movements to disperse it. There is only one time-proven compound that can be used for getting the air back toward pristine quality safely, with the fewest negative consequences for the most overall impact and speed, time-proven chemistry safety record, with the least complexity, and that is the hydroxyl radical.

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