Atmospheric scientist disproves Chicken Little

Dr. Hugh W. Ellsaesser shoots down the scaremongers who claim CFCs and the 'ozone hole' spell the doom of man. Part I of an interview assessing the scientific evidence.

Atmospheric scientist Dr. Hugh W. Ellsaesser retired from the U.S. Air Force Air Weather Service after 21 years as a weather officer and from the Lawrence Livermore National Laboratory after 24 years in climate research. He is continuing his studies at Lawrence Livermore as a Participating Guest Scientist. Rogelio Maduro interviewed Ellsaesser for 21st Century Science & Technology *on March 1.*

In the 1970s, Ellsaesser gained a reputation for being extremely rigorous in his search for the truth on the most heated scientific debates of the period. These centered around claims that such diverse phenomena as atmospheric nuclear explosions, the Supersonic Transport, the Space Shuttle, fertilizers, acid rain, and sundry other man-made things were going to poke holes in the Earth's "fragile" ozone layer. Newspaper headlines warned that a barrage of ultraviolet rays would result from man's degradation of the ozone layer, thus starting epidemics of skin cancer.

Ellsaesser and his colleagues fought to demonstrate that such fears were unfounded, and the subsequent scientific evidence has proven them correct. The only one of the "Chicken Little" claims that survived, is that chlorofluorocarbons (CFCs), one of the most useful and benign chemicals ever used and created by man, is going to deplete the ozone layer.

The CFC-ozone depletion theory was proposed by F. Sherwood Rowland in 1973 and was discounted by the scientific community. During the early 1980s, horror stories of "Nuclear Winter" abounded and the CFC issue lay dormant. Nuclear Winter was the thesis that a nuclear attack would cloud the atmosphere and cool the Earth so that even if humans survived, the plant life to support them would not be able to continue. Then, as the evidence began to prove the Nuclear Winter theory to be a hoax, the sky fell in once more, in 1985, with the discovery that there was an "ozone hole" in Antarctica, a hole in the ozone layer allegedly caused by CFCs from Earth.

The idea of a dangerous and growing "hole" captured the hysteria of the environmentalists, and the headlines. No matter that the supposedly sudden hole was actually first noticed in 1956 and deemed a natural, seasonal phenomenon by scientist Gordon Dobson. With the media's help, plugging the ozone hole became popularly accepted as a civic duty. At the end of June, officials of more than 70 nations met in London to draft a treaty mandating a complete ban on CFCs and other indispensable industrial chemicals, such as methyl chloroform, by the year 2000. The proposed treaty will have devastating impact on society; most existing refrigeration systems will have to be scrapped, and the replacements will be as much as 20 times more expensive. Many people will die from food poisoning and hunger, especially in developing nations.

Are CFCs depleting the ozone layer? Is the Antarctic ozone hole a result of voracious CFCs molecules eating away at the ozone, or is it a natural phenomenon?

In this interview, Ellsaesser examines the scientific evidence in detail, presenting a clear case for shooting down the "Chicken Littles" on the basis that there is nothing to back up their scare stories. Ellsaesser also examines the flip

side of the ozone controversy. The same ozone molecules that are seen as the saviors of human skin when they are up in the stratosphere in the ozone layer, are maligned in the lower atmosphere, where they are the main component of "smog."

The interview presents the kind of rigorous scientific argument that is missing from the environmentalist and media accounts of man-made ozone.

Q: Chlorofluorocarbons (CFCs or freons) have been taxed and are about to be banned because it is alleged that they are destroying the ozone layer. The immediate concern is the creation of an ozone hole in Antarctica. Do you believe that the ozone hole in Antarctica is a result of the use of CFCs on Earth?

Ellsaesser: The ozone hole is limited observationally to the interior of the Antarctic winter polar vortex, and it is limited theoretically to areas of temperature below about −80°C for periods of something like 60 to 90 days, the latter half of which must also have sunlight. Neither of these requirements is met on a global scale, so even if ozone is being destroyed by freons, it is limited to very specific regions of the atmosphere and specific periods of the year.

Q: What happens to the ozone hole after that?

Ellsaesser: We have the spring breakup of the winter polar vortex, and it disappears. Ozone is brought in from other latitudes and levels and fills up the hole.

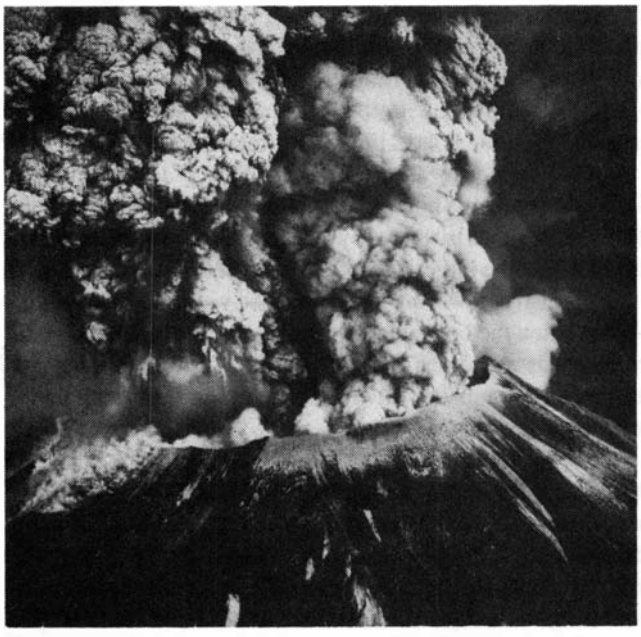
Q: Would you say, that despite the claim of the environmentalists, this is not a permanent hole?

Ellsaesser: No, it has been sporadic. In fact we have seen a two-year cycle: 1985, 1987, 1989 being particularly deep, with the intervening years being closer to normal. We don't know whether this is connected to a solar cycle or not. It is suggestive of a solar cycle, but we haven't seen enough of them to be sure. But in terms of total ozone, at the present time we have no evidence that stratospheric ozone is being depleted. All of the recent trend analyses that have been reported begin from 1969 or later. If you look back in the literature, you will find at least four reports for the period after 1962 which claim increases of 5 to 11% in global ozone in roughly a decade after 1962; that is, up to around the 1969-1972 period. Now those percentages—5 to 11%—are larger than the percentage of decrease we have seen in these trends reported since 1969. So presumably the levels of ozone we have now are higher than they were in 1962.

Q: Do we have more ozone than we did 30 years ago?

Ellsaesser: Yes, more than back in 1962. Everything I see says that and I haven't seen anyone come out with a report that contradicts that.

Q: What is the presumed role of CFCs in causing the ozone depletion?



The surest way to get ozone-destroying chlorines into the upper atmosphere is through "direct injection"—i.e., a volcanic explosion. Shown here is the May 18, 1980 eruption of Mt. St. Helens, which ejected an estimated 1 km^3 of rock and ash. The plume reached over 20 km into the atmosphere.

Ellsaesser: Everyone now admits that a very special combination of dynamics (atmospheric motions) and chemistry is required if chlorine is actually the cause of the ozone hole. While I am not convinced that chlorine is responsible for the hole, I see no way to rule it out at the present time. If chlorine is responsible, then several things have to occur in sequence:

First, the chlorine-containing compounds such as freons (CFCs), stable enough to survive in the troposphere, must ascend through the tropical tropopause into the stratosphere to a high enough level to encounter sufficiently energetic (sufficiently short wavelength) ultraviolet solar radiation to break them down chemically and release the chlorine atoms.

Second, air temperatures of about −80°C or colder must occur to condense the vapors of nitric acid and water into solid particles of nitric acid or water and nitric acid. (Such temperatures occur only within the vortices that form as a result of radiative cooling in the absence of sunlight in winter over the poles—and at the tropical tropopause where there is very little ozone to be destroyed.) These particles must not be warmed and reevaporated before they undergo gravitational fallout—a matter of weeks.

Third, after the particles have fallen out, sunlight must return, converting the ambient gaseous chlorine compounds into forms capable of catalytic destruction of ozone. (Had the nitric acid not been removed, the sunlight would have converted it into oxides of nitrogen which would combine with the chlorine and keep it from attacking the ozone.)

Fourth, this latter state must persist long enough for the catalytic destruction to become significant—again a matter of weeks. Premature termination of this process by the early spring breakup of the north polar vortex is believed to be the reason the ozone hole is limited to Antarctica.

It is noteworthy that in 1987, in the 12- to 20-km layer in which the ozone hole occurs, ozone was reduced to essentially zero—that is, there is no room for the Antarctic ozone hole to become larger or more severe than it was in 1987.

It is also noteworthy that during the years 1985 1987, and 1989, when the ozone hole was deepest, the Antarctic polar vortex was no colder than normal but it persisted later into the spring by a matter of weeks, resulting in colder monthly mean temperatures.

Q: You mean it did not warm up as soon as it should have under normal circumstances?
Ellsaesser: It did not warm up as soon as it normally has in the past. In those particular years, the longer the delay in the warming, the deeper the hole. And at the same time that you have these unusually cold mean temperatures at those levels, you had unusually high mean temperatures at levels much above there. In other words, it's indicative of what we see in the Northern Hemisphere when we have a sudden polar stratospheric warming. It's a dynamic overturning. Any time that there is that much going on in the atmosphere in terms of dynamics, there is no way of ruling out the possibility that the dynamics alone might be responsible for the ozone hole.

Q: In his original papers on the ozone layer, Gordon Dobson [the scientist who first noticed the seasonal thinning in the ozone layer in 1956] made the observation that the colder the temperatures in the stratosphere, the more the ozone would be depleted.
Ellsaesser: But the Dobson observations do not show the low levels that we are now finding in what we call the ozone *hole*. It was lower than we found in comparable seasons in comparable latitudes in the Northern Hemisphere by something like 150 units, but the ozone hole itself goes on down below that another 50% or so. We have only been able to see that since about 1979, when it started dropping rather drastically down to these levels in the Southern Hemisphere's spring. But people have admitted in the literature that if we had seen these data in prior measurements, before we had satellites to confirm them, we would not have believed them; we would simply have thrown them out, thinking there was something wrong. So it's quite possible that such measurements *were* made, and nobody recorded them or accepted them, so we have no record of them. We don't know.

Q: Dobson did observe a very pronounced thinning of the ozone layer during September and October.
Ellsaesser: Yes, compared to the Northern Hemisphere for that season and latitude, but still not to the low level of the ozone hole.

Q: A recent study that was published by Joseph Scotto of the National Cancer Institute states that the amount of ultraviolet radiation reaching the Earth has significantly *decreased* since they started measuring in 1974. Would that not also contradict the ozone layer depletion theory?
Ellsaesser: Yes, it does. It says at least that something else is operating. The so-called decrease in ozone we have seen since roughly 1975 or so—and I don't think there is much question but that there appears to be a decrease since 1975—is still not to the level we had in 1962. In other words, ozone appears to go through rather long-period oscillations. We don't know why it does.

Q: Might it be completely independent of the amount of CFCs in the atmosphere?
Ellsaesser: It could possibly be. But I don't know of any way at the present time we can completely rule out a role for chlorine. It may play the role that they have prescribed for it. But, as I said before, it has to be a very special role. The temperature must fall low enough to form ice particles large enough to precipitate, taking the nitric acid with them, for the chlorine to be able to destroy the ozone at these levels—which it ordinarily does not. However, depressed levels of nitric oxides and elevated levels of chlorine and chlorine oxide have also been found in the Northern Hemisphere, but decreases in the ozone in the Northern Hemisphere have not been found, except for one very small little dip. Now it may be that the Northern Hemisphere polar vortex breaks up so early in the year that there is not enough time for the sunlight to get there and cause the ozone destruction. That is a possibility.

Q: But more than 90% of all CFCs released are released in the United States, Japan, and Europe. . . .
Ellsaesser: There is little question that freon will eventually get to those regions. It mixes through the troposphere, ascends in the normal circulation between the troposphere and the stratosphere up through the tropical tropopause, and spreads into the stratosphere, where it is decomposed by solar ultraviolet and releases chlorine. I don't see any particular reason to question that.

Q: If the CFCs were to deplete the ozone layer, would it not happen first over Europe, Japan, and the U.S.?
Ellsaesser: No, not at the levels of 12 to 20 km where the ozone hole occurs, because before it can act at that level, you have to have the very cold temperatures to remove the oxides of nitrogen, in the form of nitric acid, and then you have to maintain those low temperatures during a period in which you have sunlight.

Q: So, even if it were true that CFCs are depleting the ozone layer, it would never happen at the latitudes of the United

States, for example.

Ellsaesser: No, not at these lower levels according to our present understanding of the process forming the ozone hole. They presumably can cause ozone destruction over the United States and elsewhere, but at levels up near 40 km.

Q: Is it true that if the ozone layer were depleted by a few percentage points—I believe 5 to 7% is claimed as the final depletion one hundred years from now if CFC production and use continues—there will be an increase in ultraviolet radiation at the surface of the Earth?

Ellsaesser: The numbers they get depend very much on the other things that are included, like carbon dioxide, nitrous oxides, and many other things, because they all tend to interact. But basically, the argument that the National Academy came up with is that a 1% decrease in stratospheric ozone is equivalent to a 2% increase in skin cancer incidence. Well, a 2% increase in skin cancer incidence in the United States, where we have data, is equivalent to a 12-mile displacement toward the equator. So if you are talking about a 5% decrease in stratospheric ozone, that's equivalent to a 60-mile displacement toward the equator. I don't think many people find that very serious.

On the other hand, ultraviolet radiation is a two-edged sword. It not only causes sunburn and skin cancer, it is also the only source that vertebrates, including humans, have for getting vitamin D, except for humans who are starting to put vitamin D in our milk. But while we have something like 300,000 to 600,000 cases of skin cancer a year in the United States—the figures tend to vary a little—we have twice that many bone fractures a year due to osteomalacia, which is degeneration of the skeleton that occurs among the elderly. Presumably the main cause of this degeneration is that during their growing years, these people didn't have sufficient vitamin D and/or calcium, or some other needed mineral. So an increase in ultraviolet—which would presumably result from a decrease in ozone—would presumably give people more vitamin D and help them develop better skeletons, so that they would be less likely to suffer from osteomalacia and bone fractures in later life.

These bone fractures from osteomalacia are really a far more serious medical problem than the ordinary type of skin cancer. As I say, we have twice as many cases in this country each year as we do of skin cancer. So an increase in ultraviolet might very well yield a net benefit for the population, although it might take a few years before it was noticeable.

Q: D you think the news media should not be creating alarm about an alleged increase in ultraviolet?

Ellsaesser: I don't think so. I think there is good reason to believe that it might very well be a net benefit. If you think about it a little bit, our bodies, which both need ultraviolet and suffer from too much of it, are much better at telling us when we are getting too much than they are at telling us when they are not getting enough. If we get a sunburn, we realize something has happened and we can start protecting ourselves. If we are developing bad bones or rickets, we don't know what is causing it and we don't do anything about it—unless we go to a doctor and he tells us. And recovering from rickets is not as easy as recovering from sunburn.

Q: What about the scare stories that minimal increases in ultraviolet would destroy entire crops and vegetation?

Ellsaesser: I don't find any evidence of that. Ultraviolet varies on an annual mean basis about fiftyfold between the equator and the poles. It doubles in about 15,000 feet in elevation at any particular location. I don't know of any case where a plant has been found not to be able to grow because of ultraviolet—even over that extreme range.

Q: Then where does the evidence come from for the scare stories being circulated by groups like the Natural Resources Defense Council?

Ellsaesser: It apparently comes from laboratory experiments. I mean, it's very clear that there are some places where ultraviolet is causing damage. We see it with sunburn, we see it with skin cancer. There are some animals and plants that live in the ocean that apparently undergo damage, but it is something that has been going on all the time. It is going on now—without any of the projected increase. And they have been able to survive. They have ways of surviving—it may simply be their very rapid multiplication. The ones that are protected by deep enough water survive, the others don't, possibly.

Q: Do you mean that it's no different than the existence of shifts in temperature that kill crops and other plants?

Ellsaesser: Yes. We've got frosts killing plants every year, after all.

Q: Coming back to the study by Scotto, what is actually being measured on the ground is exactly the opposite of what the ozone depletion doomsayers claim. No increase in ultraviolet has shown up.

Ellsaesser: That's true. There is something else that is counteracting the so-called decrease in ozone. The decrease in ozone has not shown up as an increase in ultraviolet as of now. What that other thing is, we don't know. Some people think it might be urban pollution, but I am very skeptical of that, because all the data we get from the EPA shows that urban pollution has been going down over this period.

Q: Is there no explanation as to why ultraviolet is actually decreasing?

Ellsaesser: No, no definite explanation. But some believe it is because cloudiness has been increasing.

Q: Now in terms of the stratospheric chemistry itself, have

CFCs ever actually been observed destroying ozone molecules in the stratosphere?

Ellsaesser: CFCs have been observed. CFC decay products—chlorine—have been observed. The chemistry has been reproduced—in certain stages at least—in the laboratory. But any observational evidence is at this point rather questionable. Now there was a rather sharp drop in stratospheric ozone in 1983, which was just after El Chichón, the volcano [in Mexico], erupted in 1982. It may well have been that that was due to chlorine. But I don't know of any way to substantiate that. We don't have any other explanation for that rather rapid drop in ozone at that time. That is one possibility—that it might have been due to chlorine from El Chichón.

Q: This is natural chlorine emitted by a volcano. Are there any other natural sources of chlorine in the atmosphere?

Ellsaesser: Yes, there are other compounds that are released—not in as large a volume, perhaps—that take chlorine up. There is lots of chlorine that comes out of the ocean and gets released into the atmosphere. But most of these compounds are washed out before they can get carried to the stratosphere. The only way you can hope to get significant chlorine into the stratosphere is by direct injection from a volcano, or by a compound which is nonsoluble and stable, such as the freons, until it gets up to the stratosphere, where it is exposed to very energetic ultraviolet that decomposes it. . . .

Q: One of the questions that certain volcanologists have raised concerning depletion of stratospheric ozone, is whether what the satellites are reading is really an increase in the amount of sulfur dioxide, because sulfur dioxide will brighten the stratosphere. They argue that the increase in the amount of volcanic activity in the 1980s—compared to the 1970s when the satellites were launched—would account for the increase in the brightness of the stratosphere.

Ellsaesser: Particles of any type interfere with the so-called Umkehr method of measuring ozone in the stratosphere. This is a measurement made from the ground by measuring scattered sunlight at different zenith angles. Particles, which are the things that ultimately result from sulfur dioxide in the stratosphere, interfere with that and give you erroneous readings—either an increase or decrease depending on the relative positions and when you are taking the observation. There is reason to believe that the El Chichón eruption in 1982 put enough sulfur dioxide into the atmosphere that it interfered with these Umkehr soundings during the period. But people have gone back and made corrections for this on the basis of what we know about the particles, which have been observed from satellites and lidars. So I don't think that is a serious criticism of what they are coming up with. It might help explain the dip we saw back in 1983, which we haven't been able to completely eliminate, and there was another dip—I think about 1985; I don't remember specifically.

This so-called decrease since around the mid-1970s was concentrated in these two rather sharp dips. One around 1983 after El Chichón, and the other approximately at the time of an El Niño, and people have suggested that these events may have been responsible for the dips. But we haven't yet seen a recovery—as would be expected if these were the causes.

Q: Do you see any relation between the amount of ozone in the stratosphere and the solar cycle and the very intense solar activity going on right now?

Ellsaesser: Several people have tried to make such claims, and the models compute that there will be something like a 1.5% change in total ozone—I believe—between solar minimum and solar max. But those numbers are rather small compared to the trends that have been claimed for the last 10 years, or the earlier trends after 1962, so I don't think they are sufficient to explain all that we are seeing.

Q: Faraday described how ozone and other gases react to magnetic fields, which would explain how changing the magnetic field of the poles would affect the ozone layer at the poles.

Ellsaesser: The magnetic fields themselves change rather slowly—requiring thousands of years—so I don't think they would be involved. You might get a more rapid change from solar effects—the so-called solar magnetic storms.

Glossary

Ozone layer: Layer where ozone molecules, O_3, are created and found. Starts at approximately 80 km altitude all the way down to the surface of the Earth. While the highest concentration of ozone molecules are found at the bottom of the stratosphere, around 30 km altitude, most popular press have incorrectly drawn an imaginary thin line at 30 km altitude, as if that were the layer's location.

Troposphere: Layer of the atmosphere extending from about 11 to 16 km altitude and characterized by clouds and convection. Temperature decreases rapidly with increasing altitude.

Tropopause: Upper limit of the troposphere.

Stratosphere: Layer of the atmosphere above the troposphere, in which temperature changes little with altitude and clouds are rare.

Thermosphere: Highest layer of the atmosphere that begins at about 50 miles altitude. Its temperature increases steadily with increasing altitude.

Q: Concerning the current claims about the ozone hole being a result of CFC emissions, does the theory proposed by Sherwood and Molina predict the existence of the ozone hole?
Ellsaesser: Their original theory did not. None of the models up until the hole was observed in about 1981—rather, using 1981 data—had ever predicted it. And they had to come up with a new, ad hoc chemistry to try to explain what was going on. The ad hoc chemistry, as I have explained before, begins with the requirement of very cold temperatures and goes on from there. It has all had to be developed as a result of the observations, rather than before the observation of the hole. I don't think anyone feels very comfortable with the claim that the slow increase in chlorine from freons caused the ozone hole to appear and proceed to the 1987 stage of essentially zero ozone in the 12-20 km layer in less than a decade.

Q: So perhaps the polar ozone hole—the only direct evidence that there is any ozone depletion—may just be a dynamic phenomenon without any CFCs involved?
Ellsaesser: In my opinion that cannot be ruled out. On the other hand, neither can the action of the chemistry that they have claimed be completely ruled out at the present time.

Q: In the history of the debate over the ozone hole, there were claims in the 1970s that many different human interventions, including atmospheric nuclear explosions, the Supersonic Transport (SST), the Space Shuttle, and fertilizers, were all going to destroy the ozone layer. Whatever happened to those claims?
Ellsaesser: My colleague Don Wuebbles here at Livermore still believes that the dip in 1962 was due to the Russian H-bomb that was exploded at that time. But several other people who are meteorologists or have a meteorological background, including Jim Angell, have looked at the data several times, and they don't think that the H-bomb could have had that effect. The reason is that the change was substantially smaller than the model computed it to be, and the recovery period afterwards was substantially longer than would be anticipated from a single injection of nitric oxides from the explosion. For these reasons, they discount that claim.

Q: What about the other claim, that the SST was going to obliterate the ozone layer?
Ellsaesser: It is based on the same type of chemistry—the chemistry of the nitrogen oxides. We have never tested that, because we didn't put the SSTs up. I personally have felt that we have had an observational contradiction to that theory for some time—in the so-called sudden stratospheric warmings. This is what happens in the Northern Hemisphere polar vortex about every fourth spring. It is quite suddenly destroyed and warmed up. When this occurs, large amounts of air from higher levels are brought down to around 30 kilometers, and this air from higher up has substantially higher levels of nitric oxides in it, because it is created up in the thermosphere. And yet, in the years in which that happens, we not only have an elevated ozone level in the springtime; it remains above normal throughout the summer. This says to me that the oxides of nitrogen that were brought down haven't had any effect on it. I don't know of any other observational evidence for it.

Q: That would indicate that the nitrogen oxides that would be released by the Space Shuttle and the SST would not affect the ozone layer.
Ellsaesser: Yes, but this is a rather extended extrapolation of the data in terms of observational evidence. We know that the oxides of nitrogen increase with altitude, and we know that when this air comes down from above, it will bring elevated levels, but we don't have any quantitative measure of what those levels are or whether there is some other factor involved that might keep them from attacking ozone at that time.

I think the main point to make here, is that to create almost any one of these environmental "hazards," you have to use a one-way filter in looking at the effects cascade of man's actions. In other words, examine only those pathways that lead to detrimental effects, and carefully seal off the others, so that nobody is aware of them. Otherwise, you would wind up with as many of man's actions having effects that people would consider net benefits. I think the destruction of some of the ozone layer may very well be a case of net benefit.

Q: The Clean Air Bill has an entire title devoted to stratospheric ozone depletion and the measures to deal with it. The bill calls the ozone layer "an exhaustible natural resource." Could you give us an idea of what the ozone layer is and how it is created and maintained?
Ellsaesser: It is created by energetic ultraviolet light impinging on molecular oxygen (O_2), and causing it to separate into oxygen atoms. These atoms then combine with another oxygen molecule to form ozone (O_3). There is less-energetic ultraviolet which then impinges on the ozone and causes it to go back the other way. But the ozone layer is a net result of these processes going on in our atmosphere.

I don't see any way in which we could hope to destroy that layer completely. We might be able to put something up there that might reduce it somewhat, but anything that you mix up into the stratosphere has a lifetime of about two years, because of the continual circulation between the troposphere and the stratosphere, so it will eventually be brought back into the lower troposphere. It doesn't just stay up there.

So it is not easy for it to have an effect, unless something that is being released continuously, like the freons, could do it. But the estimate on freons, even at the 1975 rate of production, was on the order of a 5 to 10% decrease in ozone at equilibrium. Equilibrium occurs when we get to high

Virginia Division of Tourism

The Blue Ridge Mountains of Virginia. Areas such as this that are heavily forested with evergreens create a large amount of what we refer to as "ozone pollution."

enough concentrations in the stratosphere that the destruction rate equals the injection rate at the surface. This eventually would happen, but it would take something like 75 to 100 years before you reached that equilibrium. But even so, the models computed something like a 5 to 7% decrease in ozone at that time.

I think a 5 to 7% decrease in ozone might very well be a net health benefit, because of the additional ultraviolet and vitamin D we would get here at the surface. And the only way you can make a disaster out of it is to look at it through this one-way filter that ignores the benefits, and to refuse to let the public know that a 1% decrease [in the ozone layer] is equivalent to a 12-mile displacement toward the equator. Again, I don't think the public would think that was very serious.

Q: It has been a very popular thing to move to Florida for retirement. What would be the equivalent in ozone depletion?

Ellsaesser: Suppose that involves a move of a 1,000 miles to the south. A thousand miles is essentially the doubling distance for skin cancer incidence caused by ultraviolet exposure. That's a 100% increase.

Something else that is interesting: If the Environmental Protection Agency ever succeeds in removing the smog layer from Los Angeles, they are going to get about a 30% increase in ultraviolet, and a comparable increase in skin cancer. Nobody seems to be concerned about *that*.

Q: You mean the EPA could give us skin cancers by fighting smog?

Ellsaesser: By removing smog, yes.

Q: But the environmentalists maintain that ozone at low levels is poison, and at high levels is of the greatest benefit to man. How is that?

Ellsaesser: Because they don't care what they say. They look only at the detrimental consequences, as I said.

Low-level ozone has several very beneficial effects. It is one of the chemicals that helps to scavenge all of the things that get released into the atmosphere. The hydrocarbons from plants, for example, which cause most of the hazes you see around the country. Those are decomposed by ozone and other energetic chemical reactions going on in the lower troposphere. It's what keeps the atmosphere clean. There is also a lot of bacterialcidal action accomplished by ozone, and by ultraviolet light as well. This keeps odors down and bacteria down. A lot of things are kept down by these processes that otherwise would become more noticeable, more odoriferous, more dangerous. There are substantial beneficial effects, that nobody wants to look at.

It is probably no accident that most early civilizations began in semi-desert areas—areas with lots of direct sunlight and therefore lots of ultraviolet.

Q: Could low-level ozone, which is supposed to be a poison, actually be an essential element for life to exist on Earth?

Ellsaesser: It has *beneficial* effects, yes. It keeps the atmosphere clean, if nothing else.

Q: Is it possible that the EPA standards for ozone pollution and other forms of pollution are simply not attainable because they are trying to regulate the natural atmospheric levels of these chemicals?

Ellsaesser: It is my opinion, and the opinion of several peo-

ple including the man who was in charge of the Air Pollution Control District in Los Angeles, back in the 1970s, Robert L. Chass, that the present EPA standard for ozone could not be attained in Los Angeles even if they evacuated the entire basin. In other words, the prescribed standard is *below the background* that would exist there even in the absence of man.

Q: Where would the ozone come from then?
Ellsaesser: The most likely source—suggested already by the occurrence of high ozone levels before—is hydrocarbons from plants. If you look at the records, you find that ozone goes up very sharply on hot days. There is nothing in the chemistry that explains that. The only thing that makes any sense is that on those hot days the plants have the hydrocarbons essentially boiled out of them to try to keep their temperatures down, and to keep from being scorched by the heat.

Q: You mean, instead of transpiring water, they are transpiring hydrocarbons?
Ellsaesser: Right. Plants put out hydrocarbons instead of water because they run out of water in trying to keep their temperature down. If you take the release over a whole year, it may not be very great. But it could be very significant during particular periods when temperatures are very high, particularly since the plant hydrocarbons are more reactive.

Now, not only do you have this temperature effect, if you look at the individual stations around Los Angeles and the [San Francisco] Bay Area, you find that the stations consistently recording the highest ozone are the ones that are near to slopes on which there are evergreen plants. This also suggests something. If you look back in *Science* magazine, you will find that Jim Sandburg who works for the Bay Area Air Pollution Control District found that he could explain something like 30 to 50% of the excesses in ozone for the next year from the winter precipitation. In other words, in California, we get all of our precipitation in the wintertime. That determines how much the plants can grow, and therefore how much hydrocarbon they can release the next summer. Using that argument, Sandburg was able to get a statistical relationship that explained something like 30 to 60% of the variations in ozone exceedences for the following year. That paper was published in *Science* over a decade ago [June 2, 1978].

Also, William Chameides, who is very active in this field, came out with a short paper in *Science* [Sept. 16, 1988] in which he points out that plants do put out significant amounts of hydrocarbons on the hot days, so it is there at the time you need it to produce ozone. There is also an editorial in *Science* [Sept. 23, 1988] that also points to this same thing—that in the United States as a whole, two to three times as many hydrocarbons are produced by plants as by man—and preferentially on hot days, which are favorable for ozone formation.

Q: Do you mean that the amount of hydrocarbons produced by cars and other industrial sources is smaller than the amount produced by plants?
Ellsaesser: Yes. That's correct.

Q: Is that why there are such high levels of pollution in the middle of the Smoky Mountains?
Ellsaesser: I think so, yes. That's one area in which reductions of hydrocarbons appear to have had no effect on ozone levels. They seem to have little effect in Los Angeles, as well. In fact, the Bay Area stands out as one of the few areas around the country that *claims* to have been able to reduce the ozone substantially. I think it raises questions about their measurements. If you look at their data, you find that essentially all of their improvement had occurred by 1972. By 1972, we did not have catalytic converters or any controls on nitrogen emissions in our autos. So I think that the Bay Area measurements themselves are questionable. If you look at EPA and the Air Resources Board here in California, they specifically do not compare observations since 1979 with previous ones, because in 1973 we switched from oxidant to ozone, and in 1979 there was an abrupt jump in all the data that no one understands. So they don't consider the data comparable over these two points. The Bay Area has never let that bother them.

Q: Are you saying that we cannot really compare the levels of ozone "pollution" today with those of the 1950s and 1960s?
Ellsaesser: That's right. You are looking at different things. You are looking at ozone now. Back then you were looking at what they called *oxidant*. No one has come up with a way to make these comparable.

Q: Does this mean that, no matter how draconian the policies imposed by the Clean Air Bill Congress, you may still not get rid of all this ozone "pollution?"
Ellsaesser: In Los Angeles you will *never* meet the present ozone standard, even if you take everybody out of there and let no one live there. Only by also taking out all of the measuring stations will EPA ever achieve the standard there. If you close all of the stations, of course, you will meet the standard, because you won't have any observations that exceed it!

Q: Is there any truth to the claim that this low-level ozone is toxic to human beings?
Ellsaesser: There is very skimpy evidence that it is hazardous. Almost all of the studies that appear valid to me indicate that you could triple the standard before you had any health effects. This would not bother EPA, they would sinmply claim that it's the "adequate margin of safety" mandated by the law.

To be continued.