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# A D V A N C E S   I N   F O A M   A G I N G

## A TOPIC IN ENERGY CONSERVATION

edited by Dale A. Brandreth
Chemical Engineering Department
Widener University, Chester, PA

A collection of fourteen articles on this important topic in foam insulation. Six are new articles published here for the first time and the remaining eight are important papers reprinted here. 222 pages of valuable information for anyone working in building insulation or energy conservation in enclosure heating and air conditioning. Although the scientific and research aspects are emphasized, the economics of improved insulation is discussed, and new information is presented on direct measurements of chlorofluorocarbon release to the atmosphere from foams. This is a very topical publication due to enhanced interest in the fluorocarbon-ozone controversy as well as energy conservation.

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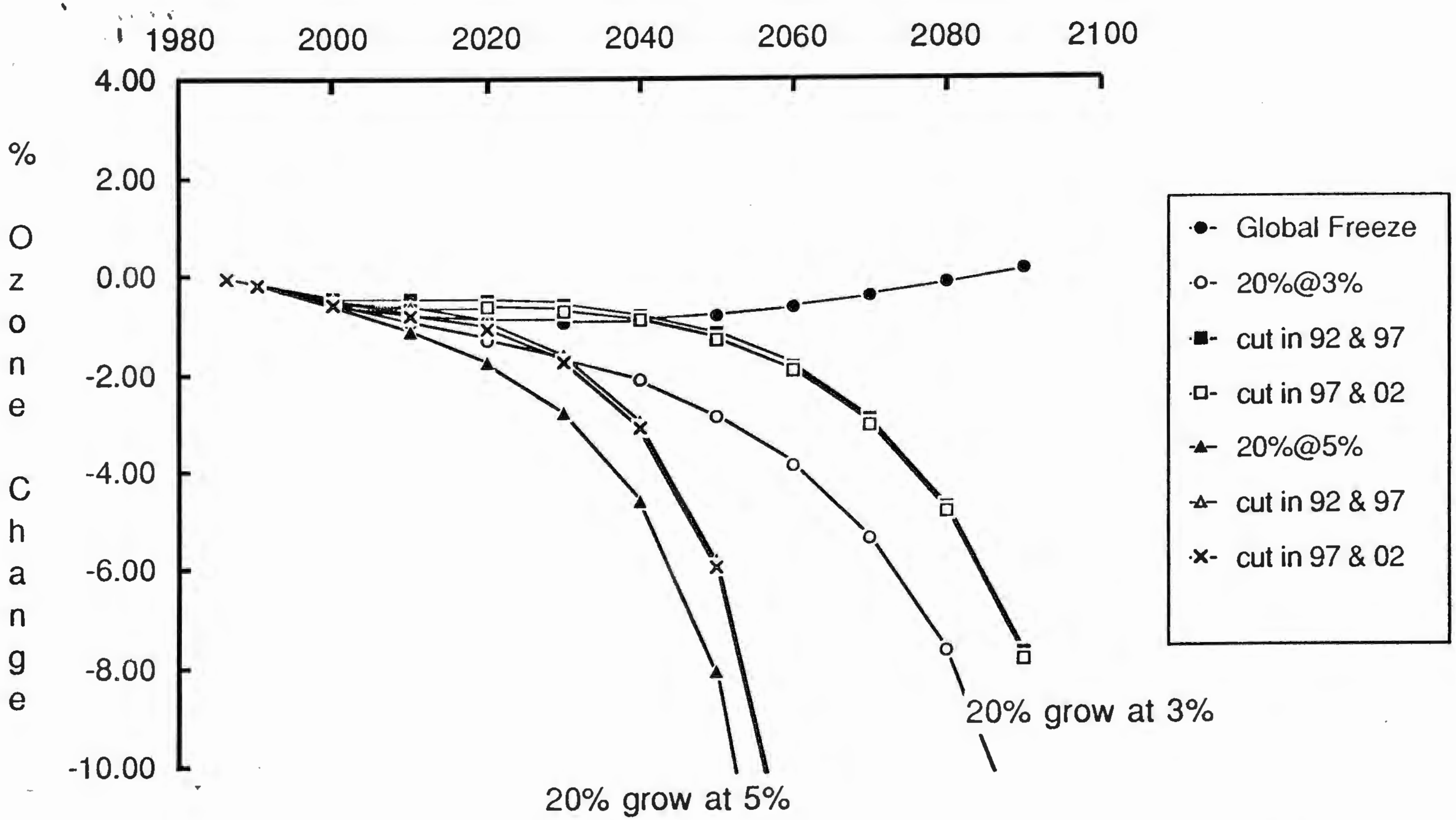
**Effects of 80% compliance with freeze, remaining 20% grow at 3% or 5%/year**

**Effects of emission reductions in complying 80%:**
**--20% cut in 1992 followed by 30% cut in 1997**
**--noncomplying 20% continue to grow at 3% or 5%**

**Effects of delaying emission reductions by 5 years (to 1997 and 2002)**



Bob

## THE DEPLETION MECHANISM

Man-made chlorofluorocarbons (CFC's) and halons are compounds which are widely used in industrial economies because of a variety of useful properties, including unusual chemical stability. In use, they eventually reach the lower atmosphere (the troposphere) and accumulate there. Because of their chemical stability, their lifetimes in the atmosphere are expected to be on the order of 75 to 110 years. Eventually they are slowly transported into the stratosphere ( above 10-15 km. to 50 km.).

Ultraviolet light (UV) in the stratosphere splits diatomic oxygen (O2) into two oxygen atoms, each of which combines with an O2 molecule to form ozone (O3). Ozone is also broken apart by UV into O2 and O. These processes ~~are~~ occur naturally in a long term equilibrium which balances O, O2, and O3 in the stratosphere.

CFC's and halons in the stratosphere are broken apart by UV, providing a supply of oxides of chlorine and bromine. In the stratosphere, such oxides act as catalysts, each molecule breaking apart thousands of ozone molecules and disturbing the O, O2, and O3 balance. The result is a reduction in the number of ozone molecules in the stratosphere, and greater transmission of UV through the atmosphere.

## NUMERICAL PREDICTIONS OF DEPLETION

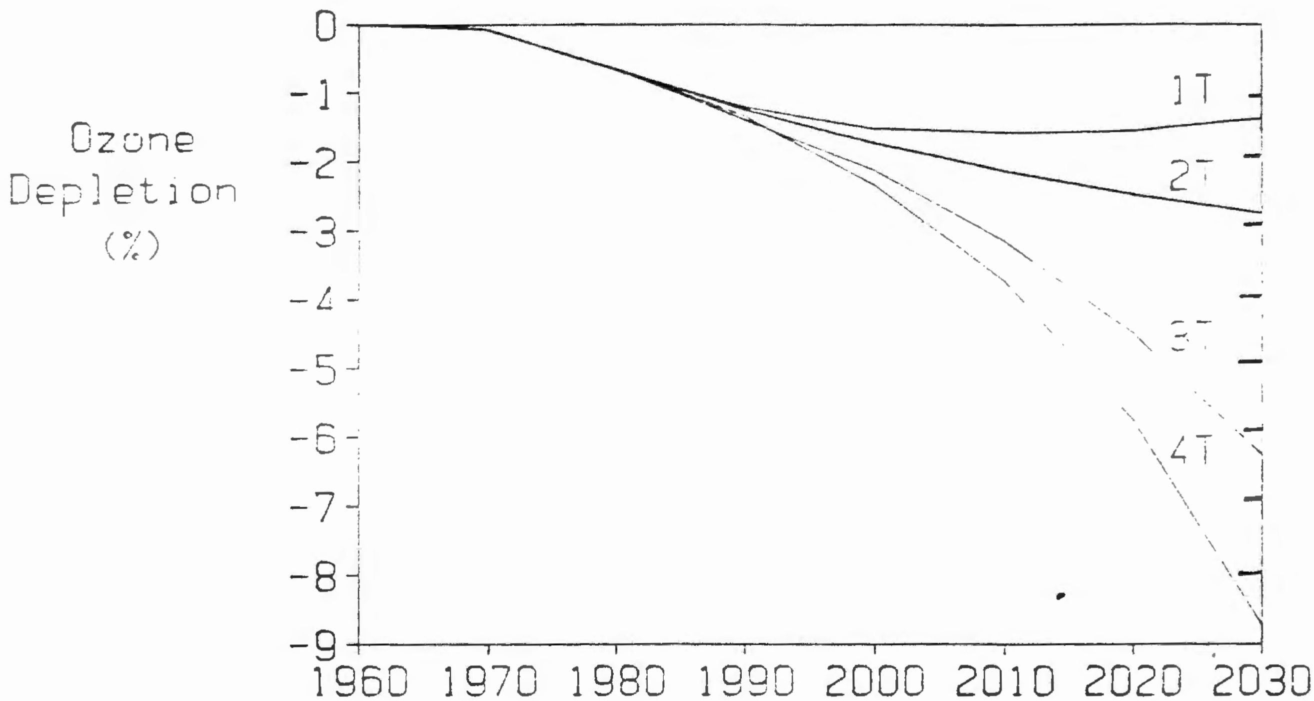
Predictions by numerical models of ozone change show significant long-term depletion of the ozone column. Chart 1 shows projected depletions for a range of CFC emission assumptions:

| Scenario | CFC-11 & 12 Emission Growth Rates, % | Ozone Depletion in 2030, % |
|---|---|---|
| 1T | Constant at 1980 | 1.4 |
| 2T | 1.2 | 2.8 |
| 3T | 3.0 | 6.3 |

Chart 1

~~EXHIBIT 5-41a~~

**Time Dependent Globablly and Seasonally Averaged Changes in Ozone for Coupled Perturbations (IS 2-D Model)**




Results show for four scenarios of trace gas growth:

| Scenario | CFC-11 and CFC-12 |
|---|---|
| 1T | 1980 levels |
| 2T | 1.2% growth |
| 3T | 3.0% growth |
| 4T | 3.8% growth |

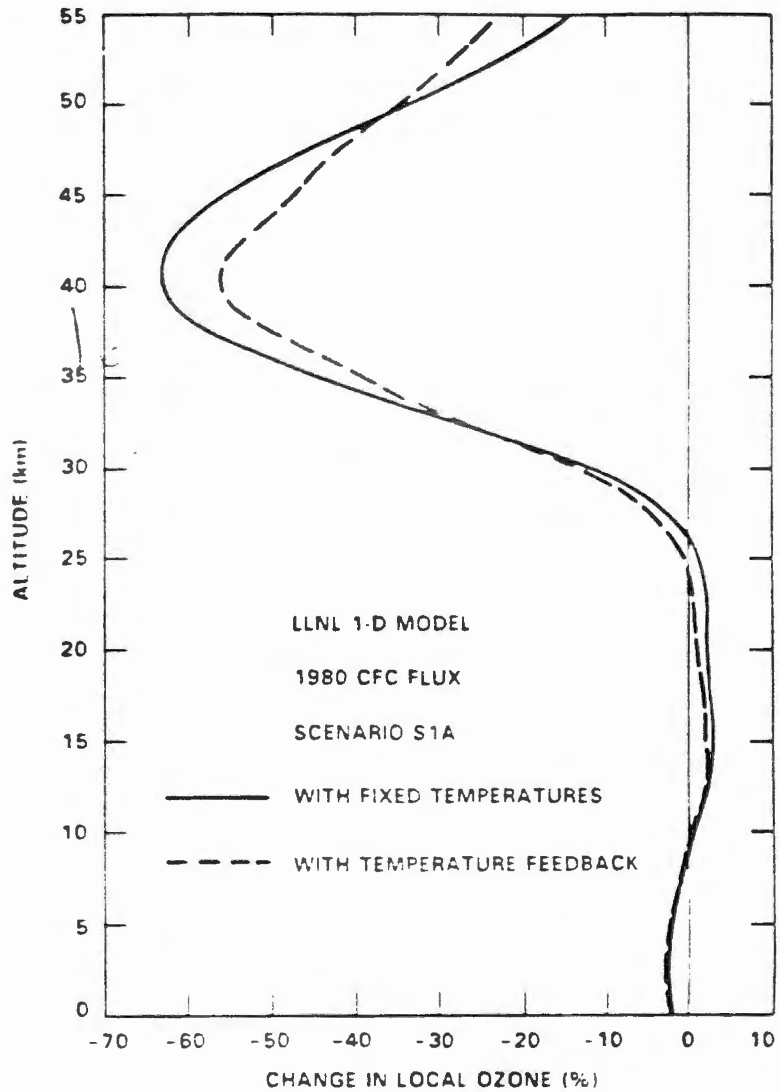
Assumptions for other trace gases are the same in each scenario: constant emissions of CFC-113, CCl4, and CH3CCl3, zero emissions of halons, one percent growth per year in CH4, and 0.25 percent growth per year in N2O. CO2 concentrations grow at 0.5 percent.

Source: Stordal and Isaksen, (1986).

CHART 2

~~EXHIBIT 5-16~~

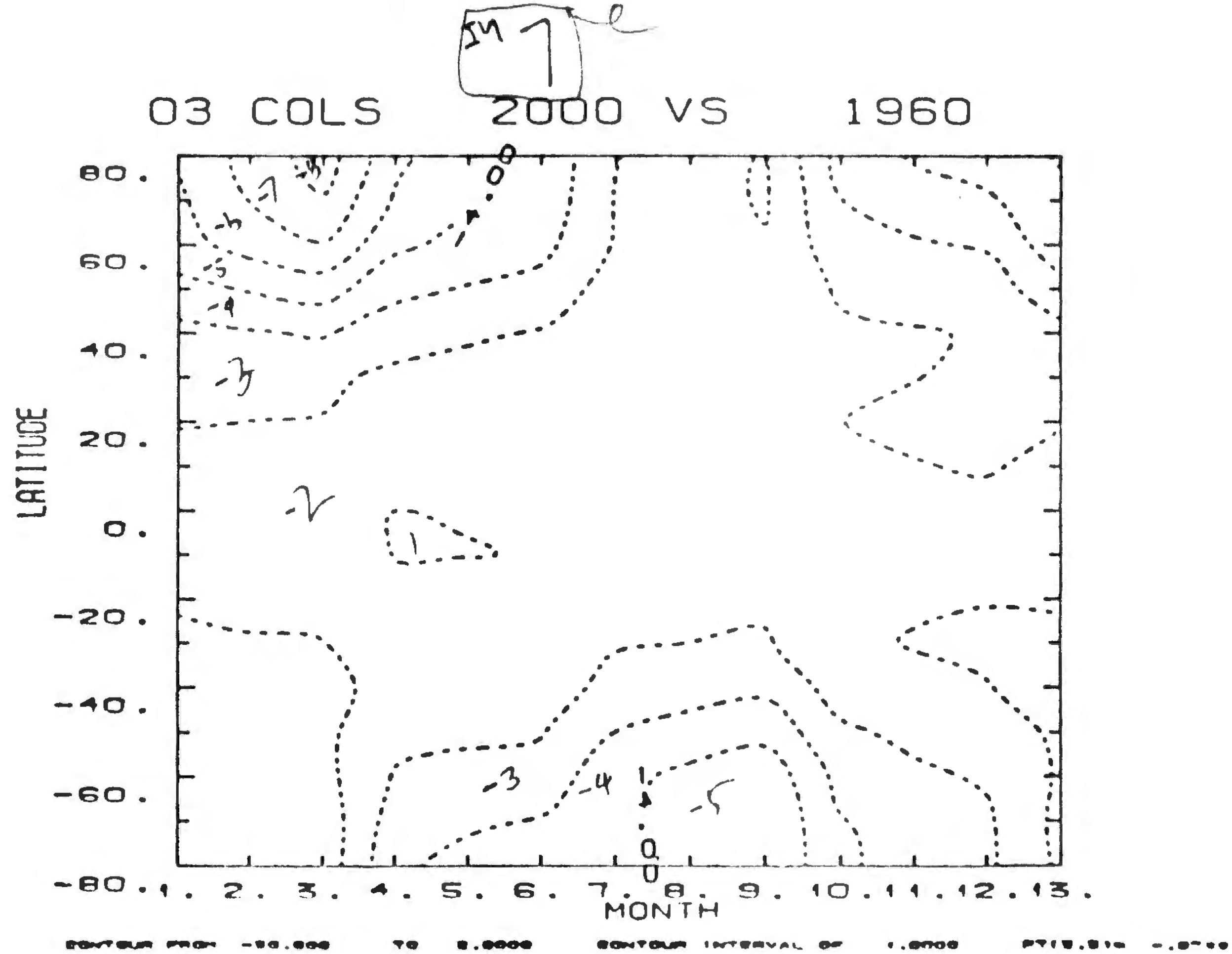
**Change in Ozone by Altitude for CFC-11 and CFC-12 Emissions at 1980 Levels (LLNL 1-D Model)**




Calculated percent change in vertical ozone at steady-state relative to atmosphere with no CFC.

Source: World Meteorological Organization, (1986).

# 2-D Analysis of Protocol
# (Isaksen model)




Assumptions:

Freeze of CFCs in 1986
25% CFC cutback from 1996 to 2000
Halon 1301 and 1211 eliminated in 1986
Methane growth 1% per year
Nitrous oxide growth 0.25% per year
Carbon dioxide growth 0.5% per year

Chart 3

| | | |
|---|---|---|
| 4T | 3.8 | 8.7 |

Chart 1 assumes uncontrolled emissions of the greenhouse gases CO2, nitrous oxide and methane. These gases mitigate the effects of CFC's in depleting ozone. However, if increases in the emission of CO2 were to be eliminated in order to reduce the greenhouse effect, the ozone depletions reached by 2030 would be increased to 2 % for CFC emissions constant at 1980 levels, to 5 % for 1.2 % annual growth in emissions and to 6.5 % for 3 % annual emission growth.

Even when predicted changes in total ozone in the column are small and hence little change is expected in the amount of UV radiation reaching the surface, major changes in the vertical distribution of the ozone are still predicted with potential consequences for climate. Chart 2 shows the vertical changes over time resulting from CFC-11 & 12 emissions held constant at 1980 levels. Such changes are expected to have a net warming effect on the climate.

Ozone depletion is not evenly distributed by latitude and by season. Chart 3 shows the predicted depletion by latitude and by season for an emissions scenario similar to the 1T Scenario of Chart 1 (emissions at 1980 levels) which reaches a depletion of 1.4 % in about 2000. The Chart 3 scenario has somewhat higher depletion than Scenario 1T because in Chart 3 emissions are continued at 1986 levels until 1996 and are then cut back to reach 1980 levels in 2000.

In Chart 3 ozone depletion reachs a maximum of -8 % in March at latitudes above 75 degrees N. A similar seasonal depletion maximum of -5 % is predicted at latitudes above 50 degrees S in August-September. The fact that winter-spring depletion at high latitudes is above the globally and seasonally averaged depletion may not be significant since at higher latitudes the ozone column is naturally at a maximum during that season. Moreover, the length of the oblique path through the column is also longer during that season since the solar zenith angle is close to a maximum. For example, at Boston (42.3 degrees N) the ozone in the column in March is normally about 12 % greater then than it is at the summer solstice. Furthurmore, the oblique path taken by sunlight through the atmosphere is 33 % longer in March than it is at summer solstice. Hence, a moderately larger depletion in March at high latitudes would imply only a minor reduction in the normal seasonal variation of UV at the surface.

## HOW GOOD ARE THE NUMERICAL MODELS?

How good are the numerical models? Ideally a model should include a relatively complete description of all of the relevant processes treated in a manner that is both three-dimensional and time-dependent. Limitations in computer resources and in the complete understanding of all the relevant processes prevents this. As a consequence, the models are in some conflict with empirical measurements. Measured ozone abundances above 35 km. exceed modeled abundances by as much as 30-50 %. Using measured abundances in radiative models results in predicted temperatures higher than those measured. Different models predict different distributions of odd nitrogen species which play an important role both in interfering with chlorine catalysis of ozone destruction and in directly catalyzing ozone destruction themselves. The current models show a variation in model sensitivity to chlorine that is only partially explained and is wider than would be expected.

On the other hand, all of the models predicted, within acceptable limits, similar ozone depletions for given CFC scenarios.

## ACTUAL TRENDS IN OZONE

Monitoring efforts to measure actual trends in global ozone have produced inconsistent and inconclusive results. Ground-based "Dobson" instruments which have been measuring ozone since 1960 at dozens of stations show no trend in ozone abundance. A much smaller number of Umkehr" stations measuring since 1970 does show a downward trend of 2-3 % for that period. However, these measurements are are very sensitive to volcanic dust and aerosols. Whether the measurements have been corrected properly for the 1982 El-Chichon eruption and the largest El-Nino event of this century -- also in 1982 -- is unknown. A third set of measurements using solar backscatter ultraviolet satellite data taken since 1978 do show a statistically significant decreasing trend in the total ozone column, largely since 1981. However satellite data also need to be corrected for sensor-drift. Whether the trend is due to sensor-drift, El-Chichon, El-Nino, changes in solar radiation, or man-made CFC's is not certain. All of these sources of ozone trend data are being re-evaluated now by a NASA-NOAA-Industry-University team which will report in late fall, 1987.

In short, interpretations of the existing satellite and ground-based data on ozone trends range from:

- -- No obvious human-caused trends, to
- -- Marked downward trends, 2-3X larger than predicted by theory.

## THE ANTARCTIC OZONE "HOLE"

It was discovered in 1985 that since about 1965 in the Antarctic spring, and only in the spring, overhead ozone has tended to disappear. This seasonally temporary depletion has been more and more each year and now amounts to 40-50 % of the ozone. This trend has unambiguously been found by a number of different measurement methods. This Antarctic ozone "hole" phenomena was totally unanticipated by the existing science. There are now a lot of different theories about the cause, including the sunspot cycle, climate change, man-made chlorine/bromine compound pollution, and others.

An effort was made in July-November 1986 to collect more detailed data about the Antarctic atmosphere. Additional major effort will be made in July-September 1987. The global implications, if any, of the Antarctic ozone "hole" are currently unknown since the cause is not established. The existing observations are consistent with but not proof of the man-made chlorine hypothesis.

## EFFECTS OF OZONE DEPLETION

Ozone depletion has a number of potential adverse impacts which are characterized in the table below:

| Area of Adverse Effect | Potential Global Impact | State of Knowledge |
|---|---|---|
| Skin Cancer | Moderate | Moderate to High |
| Immune System | High | Low |
| Cataracts | Low | Moderate |
| Plant Life | High | Low |
| Aquatic Life | High | Low |
| Climate Impacts | Moderate | Moderate |
| Tropospheric Ozone and Hydrogen Peroxide | Low | Moderate |
| Polymers | Low | Moderate |

### Skin Cancer Effects

Prolonged sun exposure is considered to be the dominant risk factor for non-melanoma skin tumors, based on epidemiological surveys. Incidence rates increase as the latitude decreases and therefore UV exposure from sunlight increases. UV-B wavelengths are the most effective in producing non-melanoma tumors in animals. These are the UV wavelengths predicted to have the relatively largest increases from ozone depletion. However, uncertainty exists in the actual doses of solar UV radiation received by populations and in the changes in response which would result from changes in dose. Changes in behavior have tended to increase skin cancer incidence and mortality. Future rates of skin cancer could be reduced if people changed their behavior.

In the U.S. there are more than 400,000 non-melanoma skin cancer cases each year. About 4000 deaths occur from these cases. The floowing table shows the range of estimates of incidence increase from a 2 % ozone depletion for San Francisco:

| Type | Current Cases (%) | Current Fatalities (%) | Increase in incidence (%) Male | Female |
|---|---|---|---|---|
| Basal Cell | 71 | 20-25 | 2.13-7.17 | 0.72-4.99 |
| Squamous Cell | 29 | 75-80 | 3.20-11.72 | 3.10-13.32 |

The non-melanoma skin cancer effects of ozone depletion are not likely to be given great weight in developing countries wishing to use CFC's -- skin pigmentation provides a protective barrier that reduces the incidence of such tumors.

Much circumstantial evidence supports the conclusion that solar radiation is one of the causes of cutaneous malignant melanoma (CMM). Whites have higher incidence and mortality rates than blacks. Whites who tan poorly have a higher incidence of CMM than darker-skinned whites. Some studies have found an increasing incidence of CMM as latitude declines and UV-B increases.

On the other hand, some studies have failed to find incidence and latitude correlations. Outdoor workers have lower CMM rates than indoor workers. Anatomic sites with lower sun exposure have high CMM rates. An emerging hypothesis postulates that intermittent exposure to high fluxes of UV-B is important in causing CMM rather than cumulative dose. EPA's estimate is that each 1 % ozone depletion will produce a 1-2 % increase in incidence and a 0.8-1.5 % increase in mortality. In 1985 there were 25,000 cases and 5,000 deaths in the U. S. from CMM.

Immune System Effects

Solar radiation has been found to have a detrimental effect on the immune system of both humans and experimental animals. Although the mechanisms are not fully understood, it is clear that UV radiation of skin reduces the immune response in that skin. It is also clear that the UV-B part of the spectrum is responsible. Immune response to infectious diseases that enter through the skin -- such as the herpes simplex virus -- is likely to be most effected. UV-B effects have not been studied in enough detail to allow estimation of dose-response relationships.

Cataracts

Scientific understanding of the physical mechanisms which cause cataracts is incomplete; it is likely that more than one mechanism operates. Some studies support the belief that some cataracts are caused by UV-B. UV-A and other causes are also considered likely.

Plant Life Effects

Existing knowledge of the risks to crops and terrestrial ecosystems from ozone depletion is extremely limited.

Data for crop species is incomplete and often not from realistic field studies. The data suggest that large variations exist within species in response to UV-B -- some varieties are sensitive, some are not. For example, in 3/4 of soybean cultivars tested, levels of UV-B simulating 16-25 % ozone depletion reduced yeilds by up to 25 %. Quality was also affected.

Little or no data exists for trees, woody shrubs, vines, or lower vascular plants. Increased UV-B could alter the results of the competition in natural ecosystems in ways that are unpredictable.

Aquatic Life Effects

Experiments have shown that UV-B causes damage to fish larvae and juveniles, shrimp and crab larvae, and to plants essential to the aquatic food web. Enhanced UV-B would probably change the composition of natural marine plant communities rather than reduce production. Such changes could cause ecosystem instabilities or cause unpredictable changes throughout the food chain.

Current data is very incomplete and limited. Understanding of aquatic organism lifecycles and of aquatic ecosystems is very limited. Great uncertainty exists about how organism behavior might reduce damage. Uncertainty also exists about potential levels of aquatic organism exposure to UV-B because attenuation of UV-B in the water column is variable.

Climate Changing Effects

CFC's, like CO2, are greenhouse gases which are essentially transparent to incoming short wave length solar radiation but which absorb and emit long wave radiation. CFC's are in fact substantially more powerful greenhouse warmers" than CO2 is by a factor of 10,000 times. Hence, increasing concentrations of CFC's in the atmosphere contribute to global warming.

Lower Atmosphere Air Pollution Effects

Preliminary scientific information suggests that increases in UV-B would increase the rates of production of acid rain precursors, hydrogen peroxide, and ozone in the lower atmosphere. These materials have health effects that are adverse. The resulting increases in violations of ambient air standards might require more restrictive measures to control hydrocarbons and nitrogen oxides in order to meet current standards.

Polymer Damage Effects

Commercial polymers have a number of important outdoor uses -- as siding, glazing, paints and protective coatings, housewares and toys, and containers. Absorption of UV-B causes photo-induced reactions which alter the properties of these materials in adverse ways -- yellowing, increased brittleness -- that reduce the life of the materials. Increasing the amounts of UV stabilizers in the materials could provide increased protection. It could also alter the useful properties, require the development of new formulations to avoid such alterations, require process changes and increase costs.

## CFC'S IN U. S. INDUSTRY

Use of CFC's in the U.S. is spread among seven use categories and a large number of applications:

| Use Category | 1985 Use (metric tons) | Percentage of Ozone Depleting Potential |
|---|---|---|
| Solvents | 41,369 | 14 |
| Refrigeration | 78,987 | 28 |
| Foam Blowing | 70,430 | 28 |
| Fire Extinguishing | 6,250 | 20 |
| Sterilization | 12,133 | 4 |

| | | |
|---|---|---|
| Aerosol Propellant | 8,000 | 3 |
| Other Miscellaneous | 7,083 | 3 |

The "percentage of ozone depletion potential" column weights the use in each category by the ozone depleting potential of the CFC compounds used. ~~Table _ shows applications within each of these use categories~~.

COSTS OF EMISSION REDUCTION

EPA has done a preliminary analysis of possible actions to reduce CFC compound use in the short, medium, and longer term. Table __ summarizes this analysis.

| Cost/Kilogram Reduced | Percent Reduction in Use (weighted by ozone depleting potential) |
|---|---|
| Short-term: | |
| <$0.15 | 30 |
| $0.15 to <0.30 | 5 |
| $0.30 to <2.30 | 10 |
| $2.30 to <7.90 | 5 |
| $7.90 and more | 11 |
| | 61 |
| Medium-term: | |
| <$0.15 | 35 |
| $0.15 to <0.30 | 5 |
| $0.30 to <1.90 | 10 |
| $1.90 to <6.60 | 10 |
| $6.60 and more | 16 |
| | 76 |
| Long-term: | |
| <$0.15 | 35 |
| $0.15 to <0.30 | 5 |

| | |
|---|---|
| \$0.30 to <1.10 | 10 |
| \$1.10 to <2.10 | 10 |
| \$2.10 to <3.90 | 5 |
| \$3.90 to <8.60 | 15 |
| \$8.60 and more | 5 |
| | 85 |

The possible actions are a large number of very specific actions for specific CFC- using applications. Chemical substitute compounds are included among the medium and long-term actions.

Given the very large number of these industrial changes, analyzed with limited study resources, some observers may question whether all of the difficulties and the likely total costs have been fully included in the EPA analysis. EPA points out that not all low cost reductions identified would be taken, some identified costs could not be estimated, and some actions are incompatible with others. However, the analysis does suggest that there are some actions which could reduce CFC use significantly at relatively moderate cost, even in the short term.

## CHEMICAL SUBSTITUTES FOR CURRENTLY USED CFC'S

The industry is looking at several possible chemical compounds which could be substituted fro CFC-11,-12, and -113. None of these compounds are now available in greater than laboratory quantities. CFC-123 appears to be a possible substitute for CFC-11 and for some CFC-113 uses, with a much lower ozone depleting potential. CFC-134A appears to be a possible possible substitute for CFC-12 and has no ozone depleting potential. Preliminary toxicology testing of these two compounds is encouraging. The two compounds appear to have the potential to replace about 45% of CFC-11, -12, & -113 use. The minimum time frame to intoduce such substitute products into commercial use would be 5-10 years. For the following reasons, the minimum time is likely to be closer to 10:

-- Publicly known production processes for CFC-123 and CFC-134A are low in yield with large waste streams that are partly toxic and partly recyclable. Long-term toxicology tests can't be done until the process that will be used in production is defined and optimized, since the material tested must include the contaminants that would be present in commercial production and contaminants are process sensitive.

-- Potential producers are unlikely to commit to a process until they are reasonably sure that significantly better ones are unlikely to be found.

-- Long-term toxicology testing can start after a process is selected and a pilot plant is built. Such testing takes 4-5 years.

-- In order to avoid potential liability, commercial users would insist upon completion of toxicology testing before adopting new compounds.

-- Users would also need a period for product compatibility/performance testing and for any product and process redesign.

-- Producers would need time to design and build full-scale plants.

Dupont has published estimates that CFC-123 is likely to have a cost that is 2-4 times that of CFC-11. CFC-134A cost is estimated at 3-5 times that of CFC-12. However, for most uses, the cost of the CFC's are a very small part of the total cost of the final product. Rigid foam board is one possible exception.

An industry estimate of future U. S. CFC consumption, without any controls, projects an increase of 55 % (3 7/16 % annually) between 1987 and 2000. Based upon this estimate, a freeze is projected to cause a price increase in real terms of 2 to 3 times within the first 3 years and four times beyond 7 years.

Given the relatively low cost of CFC's as a percentage of total product cost for most uses, one would expect the demand for CFC's to be quite inelastic so that a price increase of 100-300 % could well result from a reduction in supply of 55 %. The Natural Resources Defence Council, on the other hand, argues that a freeze would be inadequate to generate price increases sufficient to bring in substitute chemical compounds. They argue that the availability of short term alternatives would prevent a sufficient price increase under a freeze and that a 50 % reduction in availability is needed to bring in substitute compounds.

CFC CONTROL MUST BE GLOBAL

U. S. use of CFC's is not large enough that U. S. actions alone can significantly affect long term emissions. U. S. consumption of CFC-11 is believed to be about 22 % of world consumption. Its CFC-12 consumption is about 30 % of the world total.

1985 Consumption (metric tons)

| | U. S. | Other Reporting Non-communist | Communist |
|---|---|---|---|
| CFC-11 | 75,000 | 225,000 | 41,500 |
| CFC-12 | 135,000 | 230,000 | 78,700 |

CONTROL IN U. S. IS MORE DIFFICULT -- AEROSOLS ARE ALREADY BANNED

Patterns of use in the U. S. and in the other non-communist reporting countries are significantly different:

1985 Consumption (metric tons)
Other non-communist

| | U. S. | Reporting Countries |
|---|---|---|
| CFC-11: | | |
| Aerosols | 3,750 | 89,250 |
| Rigid Foam | 38,250 | 78,750 |
| Flexible Slabstock | 11,250 | 33,750 |
| Flexible Molded | 3,750 | 8,250 |
| Chillers | 4,500 | 4,500 |
| Non-allocated | 13,500 | 10,500 |
| | 75,000 | 225,000 |
| CFC-12: | | |
| Aerosols | 5,400 | 111,400 |
| Rigid Foams | 14,850 | 28,950 |
| Mobile Air Conditioning | 49,950 | 23,050 |
| Retail Food Refrigeration | 5,400 | 5,550 |
| Chillers | 1,350 | 2,300 |
| Home Refirgeration | 2,700 | 8,250 |
| Miscellaneous | 13,500 | 12,050 |
| Unallocated | 41,850 | 38,450 |

Other non-communist country use of CFC-11 is 3 times U. S. use, but their aerosol use is 24 times U. S. use. Similarly for CFC-12, other country total use is 1.7 times U. S. use , but their aerosol use is 21 times U. S. use. The U. S., Canada, and Sweden banned non-essential aerosol use in 1975, going to available substitute propellants. Current aerosol use in the other non-communist reporting countries provides an easy way for them to make substantial reductions at low cost. In those countries CFC-11 use in aerosol applications is 40 % of their total use.

CFC-12 use in aerosols is 48 % of their total use. If these countries aerosol uses were reduced to the same percentages of total use that U. S. essential aerosol uses are of its totals, CFC-11 use would be reduced by 82,100 metric tons, and CFC-12 use would be reduced by 106,450 metric tons. These reductions are each 24 % of world use. Some observers have argued that the U. S. position should be for equal percentage reductions in use after the elimination of non-essential aerosol use. Others argue that such an approach is not likely to be acceptable to countries with unrestricted aerosol use.

## STATUS OF INTERNATIONAL ACTION

B [To be added]

## STATUS OF U. S. ACTION

A [To be added]

## OPTIONS

The options below all assume:

- Coverage includes CFC-11, CFC-12, CFC-113, Halon 1201, and Halon 1311.
- An enforceable trade provision will be included to encourage compliance and ratification.
- Emissions will be defined as "adjusted production" with a credit for destruction.
- An explicit decision-making process to respond to the results of the specified scientific reviews.
- Freeze at current level on signature.

### Emission Level Issue

Option # 1: Freeze.

- Freeze at 1986 level 0-2 years after entry into force.

(A)

U.S. District Court for the District of Columbia ordered in May 1986 that the Administrator of EPA shall sign notices of proposed and final action on CFC's ~~on~~ on May 1, 1987 and November 1, 1987, respectively. Because of the continuing international negotiations, the May 1st ~~dat~~ deadline was extended to May 11. The May 11 ~~notice~~ notice could be either notice of proposed regulatory action or notice presenting a basis for a proposed decision to take no action. A notice presenting a basis for a proposed decision to take no action would be based upon the international negotiations being in process and not yet completed.

-- Complete scientific review of need for furthur reductions and hold a vote of signatories to decide action within 5 years.

Option # 2: Eliminate Non-essential Aerosol Use.

-- Establish quota baseline at 1986 level of non-aerosol use plus 5 % of 1976 aerosol use. Implement at 0-2 years after entry into force.

-- Increase baseline by 2 % per year for 10 years.

-- Complete scientific review within 10 years after initial signing.

Option # 3: Reduce by 20 %.

-- Freeze at 1986 level, 0-2 years after entry into force.

-- Reduce 20 % below 1986 level, 2-4 years after entry into force.

-- 8-16 years after entry into force, if scientific review supports and signatories so vote, reduce furthur within the range of 20-50 % below 1986 levels.

-- 14-16 years after entry into force, if scientific review supports and signatories so vote, reduce furthur within the range of 20-95 % below 1986 levels.

Option # 4: Commit to 50 % and Scheduled Furthur Reductions.

-- Freeze at 1986 level, 0-2 years after entry into force.

-- Reduce level 50 % below 1986 level, 5-10 years after entry into force, unless scientific review finds no need.

-- Reduce furthur in the range of 50-95 % below 1986 levels, unless scientific review finds no need.

<u>Implementation Issue.</u>

Option A: Market Oriented Implementation.

-- Require, among signatories, free trade in the controlled subtances.

-- Require, among signatories, free trade in production rights.

Do not include imports or exports between signatories in adjusted production.

Option B: Unspecified Implementation.

-- No specific requirement on free trade in CFC's and Halons

-- No specific requirement on transfer of production rights.

## DISCUSSION OF EMISSION LEVEL OPTIONS

Table __ compares the four emission level options over the first decade of their effects:

Table __

Consumption of CFC's (Millions of pounds)^

| Year | Option #1 Freeze | Option #2 Eliminate Non-essential | Option #3 Reduce by 20 % | Option #4 Reduce by 50 % |
|---|---|---|---|---|
| 1 | 1900 | 1483 | 1900 | 1900 |
| 2 | 1900 | 1513 | 1900 | 1900 |
| 3 | 1900 | 1543 | 1520 | 1900 |
| 4 | 1900 | 1556 | 1520 | 1900 |
| 5 | 1900 * | 1606 | 1520 | 1900 |
| 6 | 1900 | 1638 | 1520 | 1900 |
| 7 | 1900 | 1671 | 1520 | 950 |
| 8 | 1900 | 1704 | 1520 | 950 |
| 9 | 1900 | 1738 | 1520 * | 950 |
| 10 | 1900 | 1773 * | 1520 | 950 |
| | 19,000 | 16,225 | 15,960 | 15,200 |

^Table excludes eastern bloc nations. Uses 1985 numbers as the base rather than 1986.

Percentage of the Freeze option:

| | | | |
|---|---|---|---|
| Total Consumption Change | -15 | -16 | -20 |
| Ending-Year Consumption | 93 | 80 | 50 |

-- Option # 1 has the most depletion; options 2 - 4 have about the same environmental effects. Considering the results of the initial actions before scientific review and subsequent decision, options 2 - 4 produce similar results, with emission reductions ranging from 15-20 % below the freeze option. The relative emission or consumption reductions in the 2nd and following decades are undefined, since they depend upon the results of the scientific reviews specified by the options and the decisions on furthur reductions jointly made by the signatories on the basis of those reviews.

-- Furthur reductions would be most difficult from Option 1 and least difficult from Option 4. If sceintific review shows a need for furthur reductions below the level reached at the end of the 10th year, the additional reductions would be largest and most difficult to make from Options 1 & 2, and smallest and easiest to achieve from Option 4. This is so for two reasons:

  -- any option which has a higher emission in the first decade requires a lower final consumption level to achieve stabilization of depletion at a given desired level.

  -- Options 1-3 have higher consumption levels in the 10th year and hence have farthur to go to reach any given final level of consumption.

-- The freeze option (#1) is easiest to achieve, 50% reduction option (# 4) is the most difficult:

  -- Option # 1: Freeze, would be relatively easy to achieve, even the industry accepts it.

  -- Option # 2: Eliminate aerosols, would be enven easier than a freeze for the U.S., since it permits growth in non-aerosol uses. The rest of the world could also do it easily by using substitute propellants for aerosols. However, they might not agree to such an approach.

-- Option # 3: 20 % reduction, appears feasible. EPA cost analysis estimates that 30 to 35 % could be achieved quickly at low cost.

-- Option # 4: 50 % reduction, would depend on the successful introduction of chemical substitutes for CFC's. Such success appears likely, but it is not a certainty. Such a reduction could be costly and difficult in the absence of acceptable chemical substitutes.

-- Some options are more likely than others to create the incentives necessary to bring in chemical sustitutes.

-- Option # 1: Freeze, industry argues that a freeze would create sufficient incentives over a 7-10 year period. Environmental groups disagree.

-- Option # 2: Eliminate aerosols. Probably wouldn't create sufficient incentives in the first decade since some growth in non-aerosol uses would be permitted and possible later reductions are not defined.

-- Option # 2: 20 % reduction. With a projection of uncontrolled U.S. consumption increasing by 50-60 % by the year 2000, it seems likely that a 20 % reduction in available supply below the 1986 level would raise price enough to bring in substitute chemicals.

-- Option # 4: 50 % reduction. Very likely to provide sufficient incentives.

-- Some options are likely to be unacceptable to too many countries.

-- Option # 1: Freeze. Likely to be acceptable.

-- Option # 2: Eliminate aerosols. Although substitution of non-CFC propellants would be very easy, CFC propellant using countries may not accept treatment that is different from that of the U. S. and other non-user countries.

-- Option # 3: 20 % reduction. Although it is not certain, this level of reduction is likely to be acceptable to many.

-- Option # 4: 50 % reduction. Probably not acceptable at this time.

-- Option 2 gives equitable credit for past reduction - i. e., banning non-essential aerosol use; other options do not necessarily do so.

DISCUSSION OF IMPLEMENTATION ISSUE

[To be added]

Albritton, 6/2



# "CLIMATE" RESPONSES TO CHLORINE EMISSIONS: IMPLICATIONS OF CFC POLICIES

A SUMMARY OF THE PRESENT SCIENTIFIC UNDERSTANDING

PRESENTED TO THE DOMESTIC POLICY COUNCIL WORKGROUP
WASHINGTON, D.C. 2 JUN 87

PREPARED BY NOAA
NASA
OSTP
EPA

- WHERE THIS SUMMARY FITS IN ...

POLICY NEEDS: (THE BIG PICTURE)

COST/BENEFIT (e.g., $/$)

COST → ΔEMISSIONS

⇩

ΔEMISSIONS → ATMOS. RESPONSE ← THIS SUMMARY

⇩

ATMOS. RESPONSE → ΔEFFECTS

⇩

ΔEFFECTS → BENEFITS

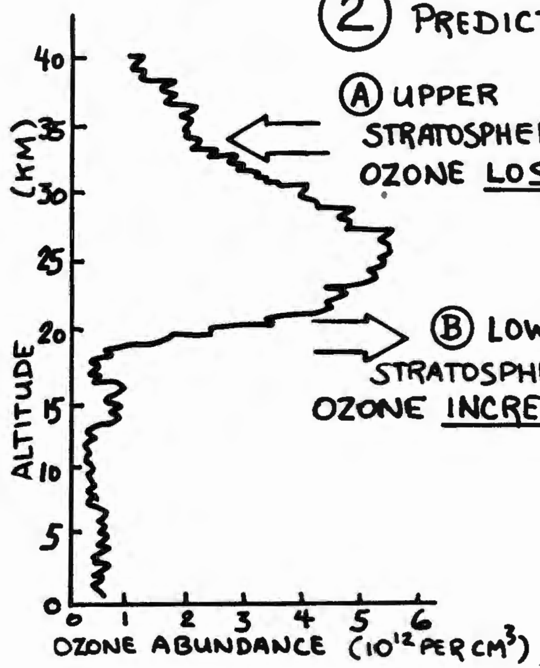
# ATMOSPHERIC RESPONSE TO CHANGING TRACE GASES: CFC's, $CO_2$, METHANE...

- TWO CATEGORIES:

1 PREDICTED DECREASE IN TOTAL COLUMN OZONE

EFFECT: INCREASED SURFACE UV

DISCUSSED 22 MAY 87




2 PREDICTED:

A UPPER STRATOSPHERIC OZONE LOSS — EFFECT: COOLING → CIRCULATION

B LOWER STRATOSPHERIC OZONE INCREASE — EFFECT: GREENHOUSE WARMING → CLIMATE

TODAY...

2A&B

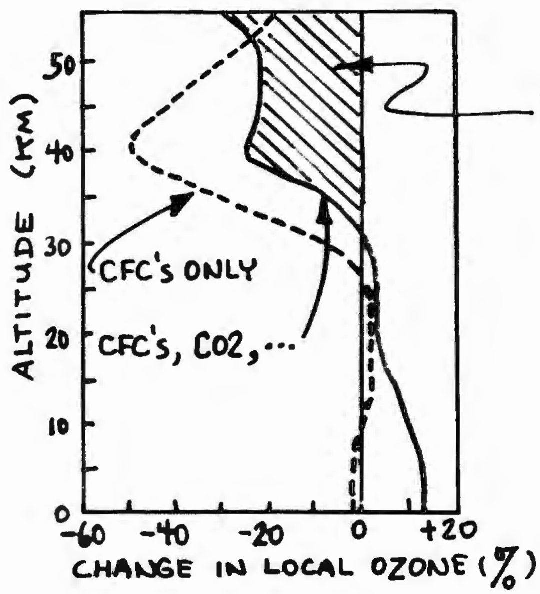
- WHAT IS THE ATMOSPHERIC RESPONSE?
- HOW WELL IS IT UNDERSTOOD?
- HOW DOES THE PERTURBATION COMPARE TO NATURAL VARIATION?

# ②A Upper-Stratospheric Ozone Loss

- **Predicted Long-term Response :** (For a true global freeze of chlorine/bromine emission rates)

Example:

- Year 2040
- CFC 11 & 12
- Freeze at 1980
- $CO_2$, methane, nitrous oxide increasing



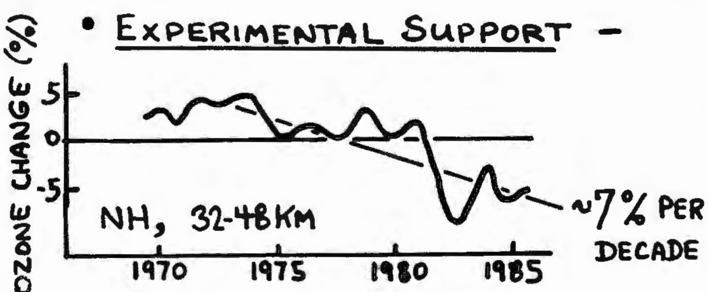

What does this loss imply?

[Policy Q: Do need more than a true global freeze?]

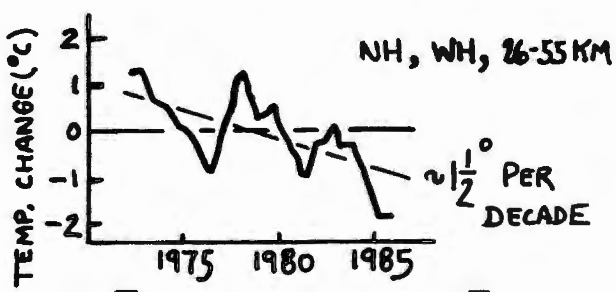
- **Current Understanding of the Atmospheric Consequences:**

  o Overall Cooling ...

  - Radiation theory says – 25% drop in ozone → ~5° cooling
  - Experimental Support –




["Umkehr" ☹]




[Rocketsondes ☹]

- But temperature/chemistry/circulation are intertwined.

  The coupled calculations are still a research problem

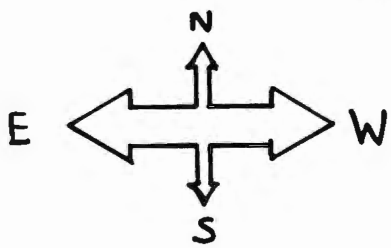
## ○ UNEVEN COOLING

- $CO_2$-INDUCED STRATOSPHERIC COOLING IS UNIFORM WITH LATITUDE.

  { NO LATITUDINAL TEMP. DIFFERENCES
  ↓
  NO CIRCULATION CHANGES

- OZONE-INDUCED COOLING IS NON-UNIFORM, I.E., THE TEMPERATURE CHANGE VARIES WITH LATITUDE.

- CIRCULATION PATTERNS:





IF OZONE LOSS...
↓
TEMPERATURE DIFFERENCES W/LATITUDE
↓
N-S CIRCULATION CHANGES MAY BE POSSIBLE ★

- THE NATURE & MAGNITUDE OF THE POSSIBLE CHANGES ARE A SUBJECT OF CURRENT RESEARCH AND HENCE ARE PRESENTLY UNCERTAIN.

## UPPER-STRATOSPHERIC OZONE LOSS ...

➡ **BOTTOM LINE:** A TRUE GLOBAL FREEZE OF CL/BR EMISSION RATES IS CURRENTLY PREDICTED TO YIELD:

- UPPER-STRATOSPHERIC COOLING, LARGER THAN THE OBSERVED '73-'86 (~NATURAL) VARIATION.
  (≈5% ws ? nat'l variation)
- POSSIBLE CHANGES IN STRATOSPHERIC CIRCULATION.

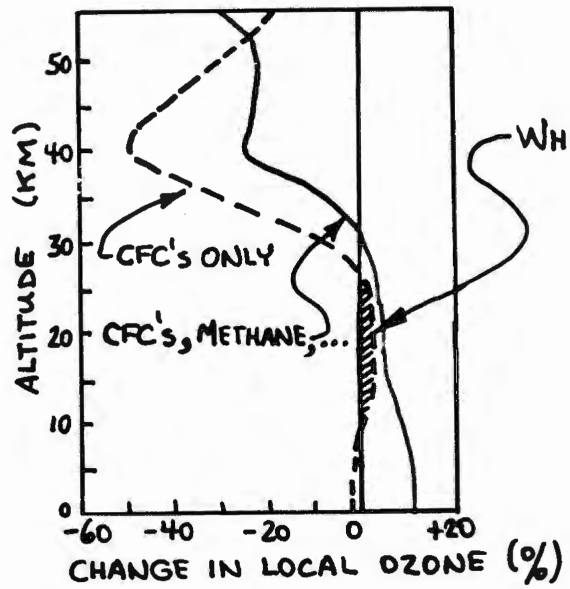
BUT, THE CONSEQUENCES OF BOTH CHANGES TO CLIMATE (I.E., SURFACE TEMPERATURES, RAINFALL,...) ARE UNKNOWN AT PRESENT.

## (2B) Lower-Stratospheric Ozone & Atmospheric CFC Increase

- **Predicted Long-term Response:** (for a True Global Freeze of chlorine/bromine emission rates)

Example:

- Year 2040
- CFC 11 & 12
- Freeze at 1980
- $CO_2$, methane, nitrous oxide increasing




What does this increase imply?

← Note: coldest altitude is here

- **Current understanding of the greenhouse warming:**

  - o Background ...

Infrared-active molecules

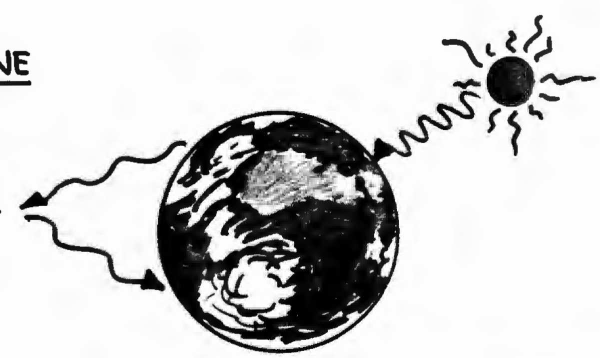
Fossil fuels → • $CO_2$

Natural, ? → • Methane

Man-made → • CFC's

• CFC/UV, • Methane, • Pollutants, • Natural → • Ozone

⋮

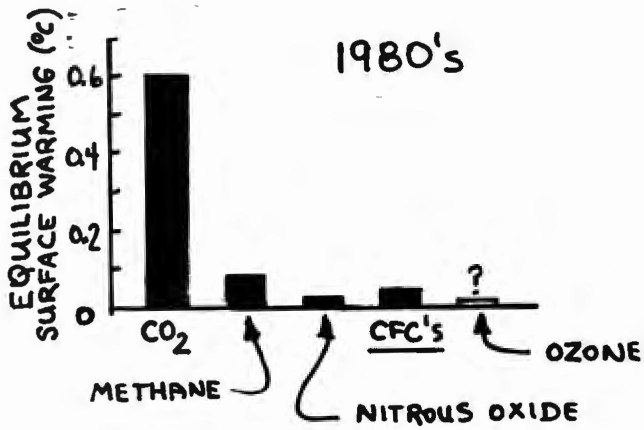


Result: Surface temperature warming

  - o What does theory say?
  - o What do observations say?

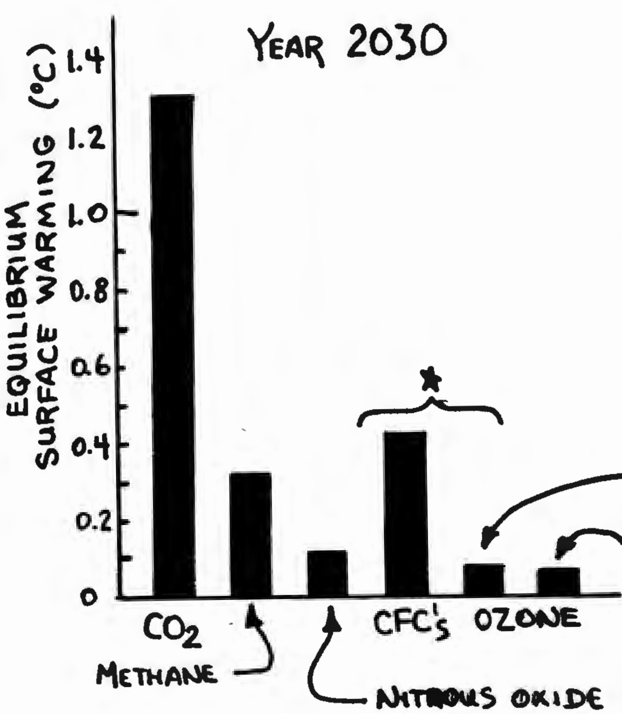
## ○ THEORETICALLY PREDICTED WARMINGS

• NOW: (EMISSIONS UP UNTIL 1980)




HENCE:
CFC EFFECT ~ 10% OF $CO_2$ EFFECT

• THE FUTURE:




GROWTH SCENARIO'S ASSUMED:

- $CO_2$ – ~0.5% PER YEAR
- METHANE – 1.5% PER YR
- NITROUS OXIDE – ~0.3% PER YR
- CFC'S – 3% PER YR (F11&12) (~ BULLISH)
- OZONE (ST) ←
- OZONE (L.ATM.) – 0.25% PER YR

STRATOSPHERIC OZONE (CFC'S, $CO_2$, METHANE, ...)

LOWER-ATMOSPHERIC OZONE (METHANE, POLLUTANTS)

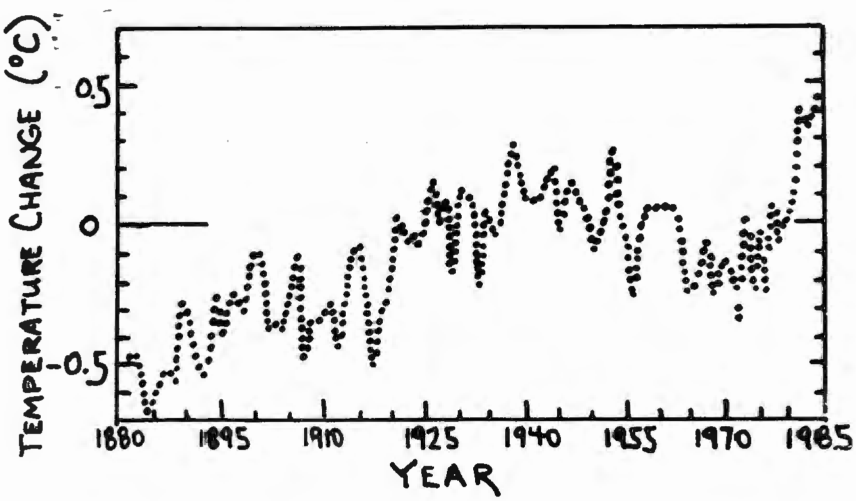
HENCE: CFC 11&12 EFFECT ~ 40% OF $CO_2$ EFFECT (3% PER YR)

[≈ 25% OF $CO_2$ EFFECT (~'80'S FREEZE)]

2B CON'T

- OBSERVATIONS

~100-YR SURFACE TEMPERATURE RECORD FOR WORLD LAND AREAS




- A FEW POINTS OF SUMMARY
  - $CO_2$ IS NOT THE ONLY GREENHOUSE SPECIES: METHANE, CFC's, OZONE, ...
  - CFC's CONTRIBUTE TWO WAYS: DIRECT – INFRARED-ACTIVE MOLECULE
    INDIRECT – OZONE PRODUCTION 15-25 KM
  - CLIMATE MODEL UNCERTAINTIES: FACTOR OF 3 (CLOUD FEEDBACK ☹)
  - NATURAL VARIATION: 0.5-0.75°C CHANGES DURING PERIOD OF LAST CENTURY OR SO

LOWER-STRATOSPHERIC OZONE INCREASE ...

➡ BOTTOM LINE: THE CURRENT UNDERSTANDING PREDICTS THAT

CFC-INDUCED WARMING OF 0.4-1.4°C 3% GROWTH RATE THRU 2030
0.25-0.8°C FREEZE IN '80's,

WHERE PAST NATURAL VARIATION OF LAND-SURFACE ~ ½-¾°C.

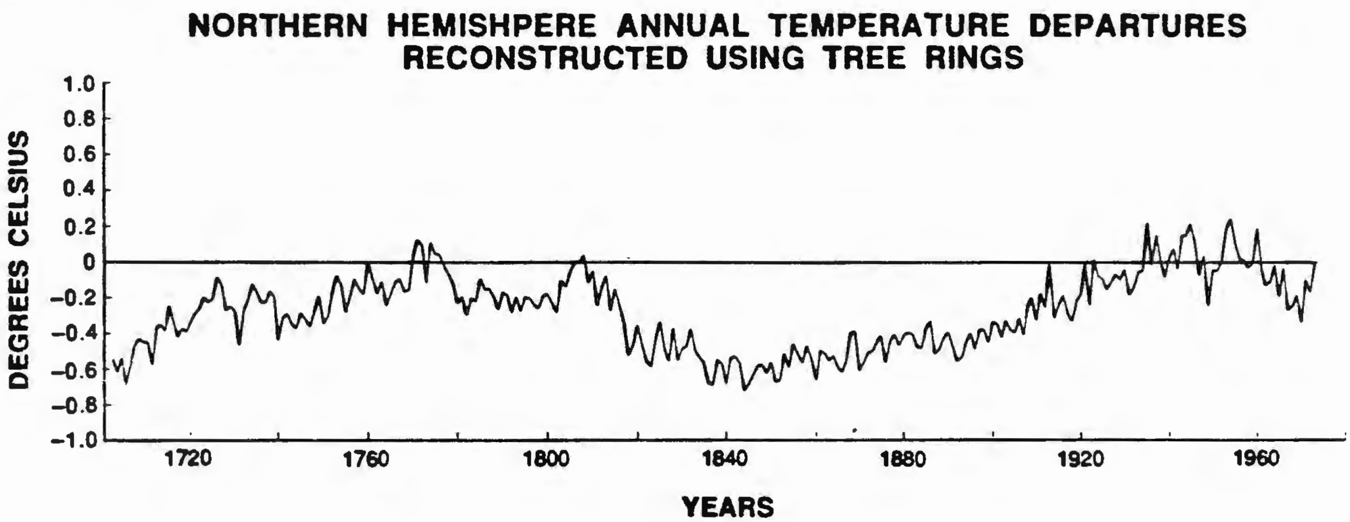
# REFERENCES


- **GENERAL:**
  - WMO, No. 16 "ATMOSPHERIC OZONE - 1985". ["THE BIBLE"]

- **UPPER-STRATOSPHERIC OZONE & TEMPERATURES:**
  - FELS ET AL., J. ATMOS. SCI., 37 2265 (1980). [THEORY]
  - ANGELL, MONTHLY WEATH. REV., ACCEPTED (1987). [TEMPERATURE TRENDS]
  - ANGELL, J. CLIM. APPL. METEOR, SUBMITTED (1987). [OZONE TRENDS]

- **LOWER-STRATOSPHERIC GREENHOUSE WARMING:**
  - LACIS ET AL., GEOPHYS. RES. LETT., 8 1035 (1981). [PREDICTIONS: 1980]
  - RAMANATHAN ET AL., J. GEOPHYS. RES., 90 5547 (1985). [PREDICTIONS: 2030]
  - HANSEN ET AL., SCIENCE, 220 873 (1983) & UPDATES [OBSERVED SURFACE TEMPERATURES]

*Figure 1. Reconstruction of Northern Hemisphere annual average temperature departures based on 11 chronologies developed from high-latitude tree-line sites across North America. The range of sites is from northwestern Alaska to northern Quebec and extends across more than 90 degrees of longitude. The 11 chronologies were submitted to principal components analysis and only the first two amplitudes were used as predictors. These two amplitudes explained over 50 percent of the variance in annual temperature from 1881 through 1975 and showed apparent stability when the concurrent temperature and tree-ring data sets were divided at 1926-27 and modeled and tested independently.*



cancers
① - need pop size & incremental amt attributable to depletion.
② w-wide data -- not availab.
③ JR - How much on Delta O3 chart is total column depletion & what amt is attrib to dev'd & dev'g.

# Presentation to DPC Working Group

④ Uncert'y in cancer deaths = factor of 2-

prepared by
EPA
and
Subcommittee on Effects
(OSTP, DPC staff, ~~Interior~~, CEA)

June 2, 1987

OSTP
① no D-R curve on cataracts? b/c no real lifetime data
② HHS

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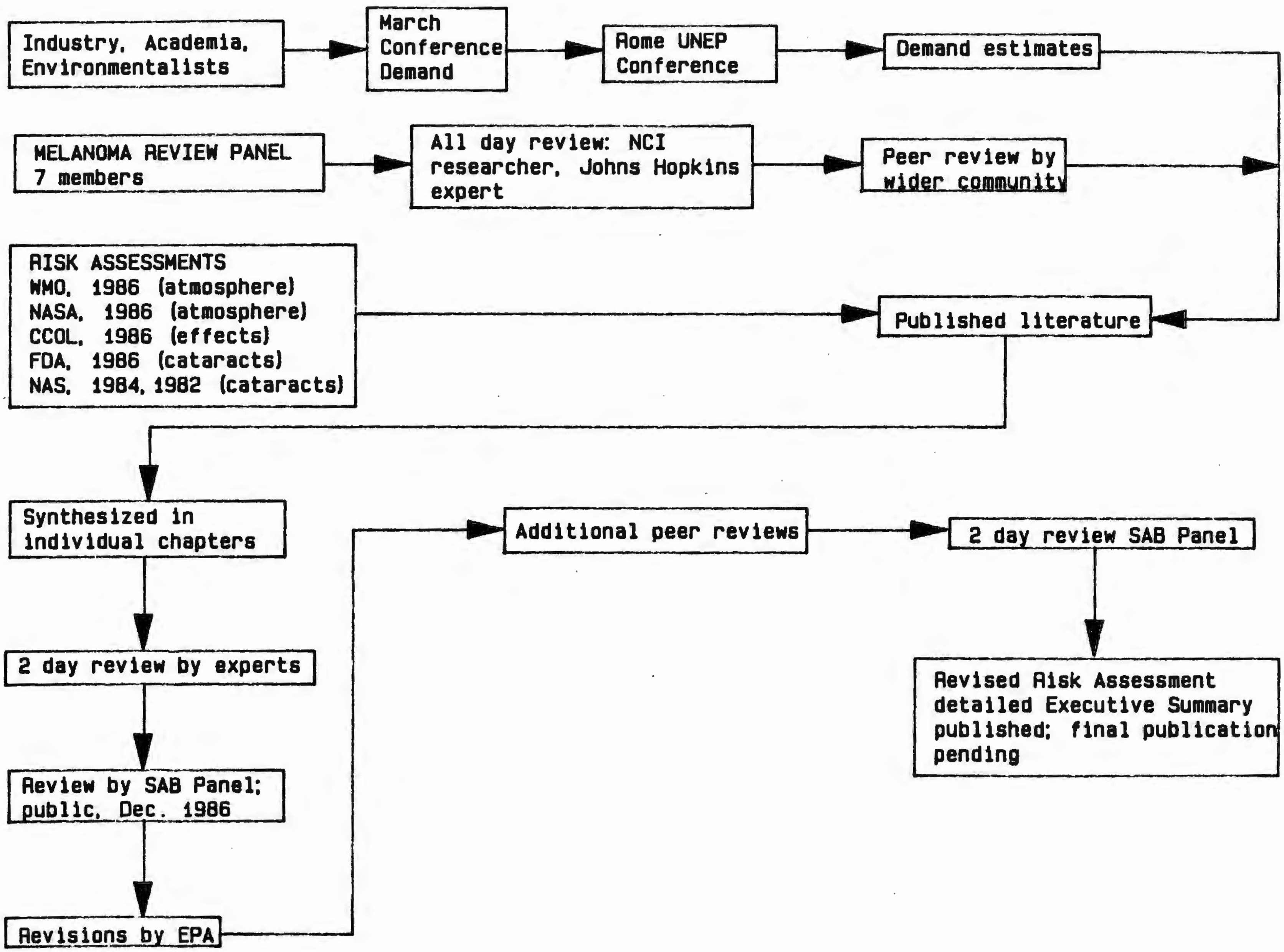
# REVIEW PROCESS



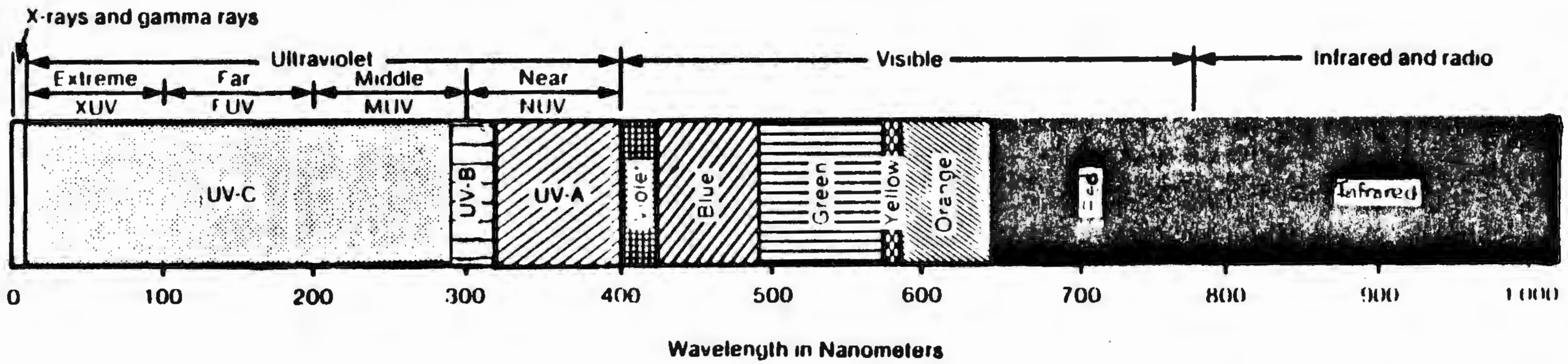
# Science Advisory Board Review Panel Overview

| | Potential Global Impact* | State of Knowledge |
|---|---|---|
| * UV-B radiation | | |
| * Skin cancer | Moderate | Moderate to High |
| * Cataracts | Low | Moderate |
| * Immune suppression | High | Low |
| * Ground-based ozone | Low | Moderate |
| * Crops | High | Low |
| * Aquatics | High | Low |
| * Polymers | Low | Moderate |
| * Climate | Moderate** | Moderate |

*Impacts can be large in U.S. and Small globally.
(e.g. skin cancers occur for light-skinned people
and ground-based ozone is not a global issue

** includes effects of column ozone redistribution, not CFCs on warming

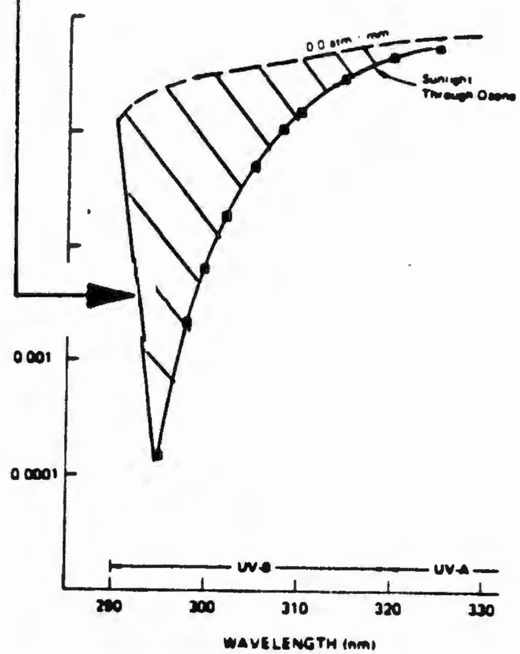
THE ELECTROMAGNETIC SPECTRUM




Source: Adapted from Scotto, 1986.

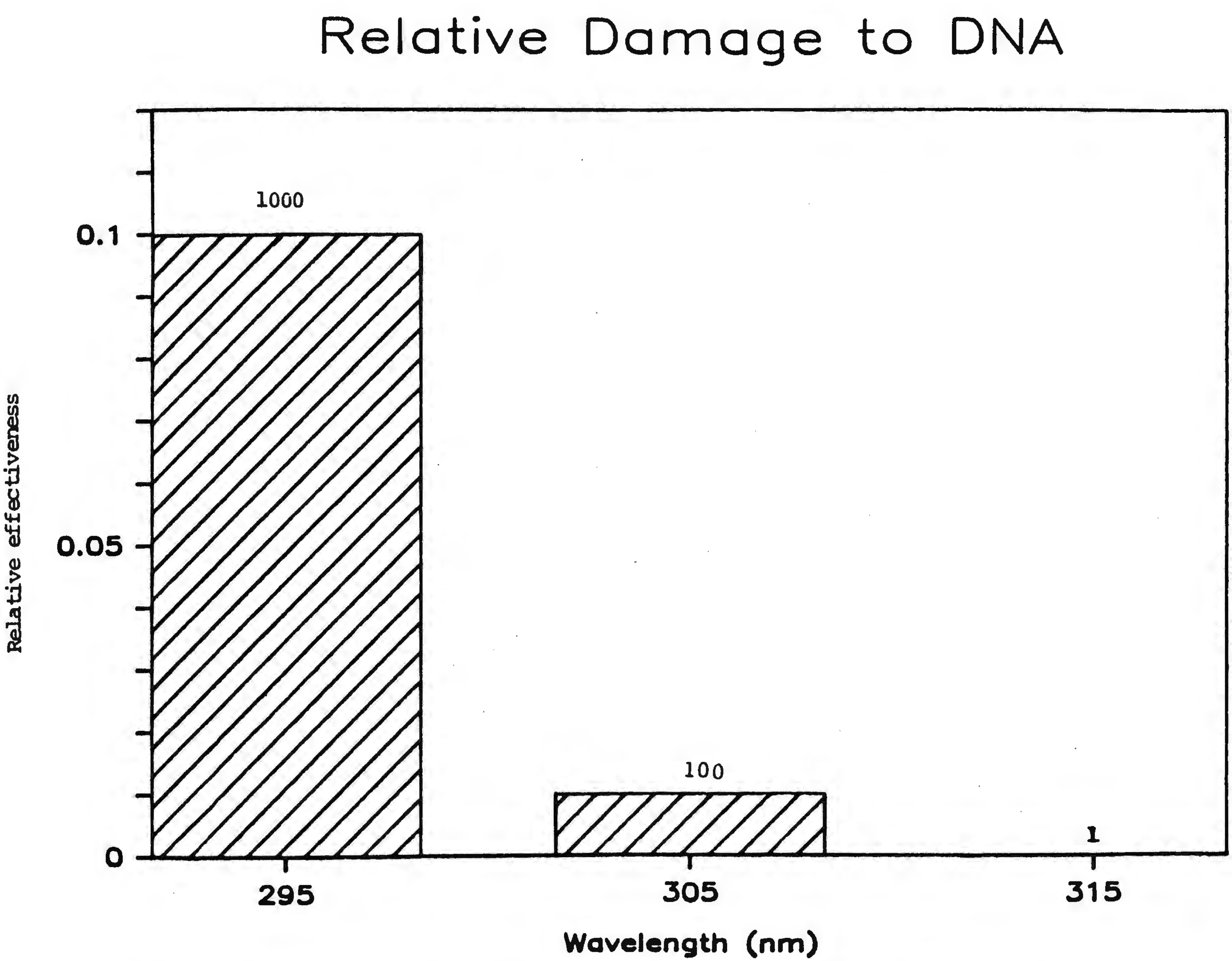
# Effectiveness of Ozone Layer in Blocking UV Radiation

Relative # of photons




* Ozone layer varies seasonally, annually, and daily
* Variation also occurs by latitude, altitude and cloudiness

Source: Adapted from NAS, 1983




DNA Action Spectrum: 1% ozone depletion leads to 2% - 3% increase in damaging ultraviolet radiation

Source: Setlow (1974)

# UV-B CAUSES SKIN CANCERS

| | Strength of Evidence on Cause | Dose | Responsiveness to 1% ozone column change (incidence) | Mortality |
|---|---|---|---|---|
| Basal | Conclusive | Cumulative | 1.5 to 4.2 % | minimal (0.31% of cases) |
| Squamous | Conclusive | Cumulative | 3.1 to 6.0 % | intermediate (3.75% of cases) |
| Melanoma | Very strong | Epsiodic | 1.1 to 2.0 % | worst (1% depletion yields 0.7 to 0.9% increased mortality) |

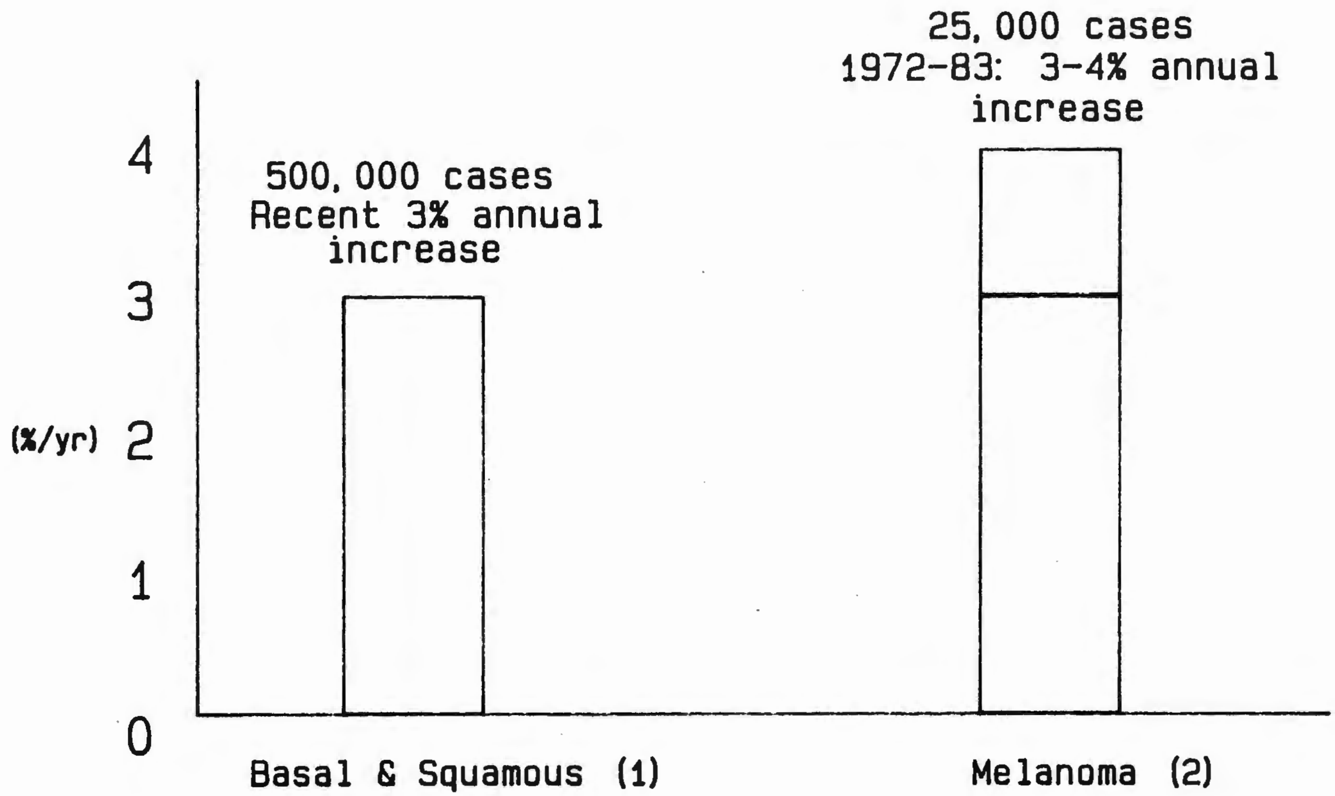
Sources: Estimates from EPA Risk Assessment and Scotto, (1986), "Nonmelanoma Skin Cancer - UV-B Effects" and Pitcher (1987), "Melanoma Death Rates and Ultraviolet Radiation in the United States"

# EVIDENCE ON UV-B AND MELANOMA

| | |
|---|---|
| Xeroderma patients (lack DNA repair for UV-B) | * 40 times rate in normal population |
| Sunburn history / Skin color | * Higher rates |
| Cases controls in Australian studies | * Weekend sailors have higher rates<br>* Episodically exposed sites have highest rate |
| Indoor workers higher risk | * Related to episodic exposure |

**CURRENT BELIEF FOR KEY FACTOR: EPISODIC EXPOSURES**

# SKIN CANCER RATES ARE INCREASING IN U.S.

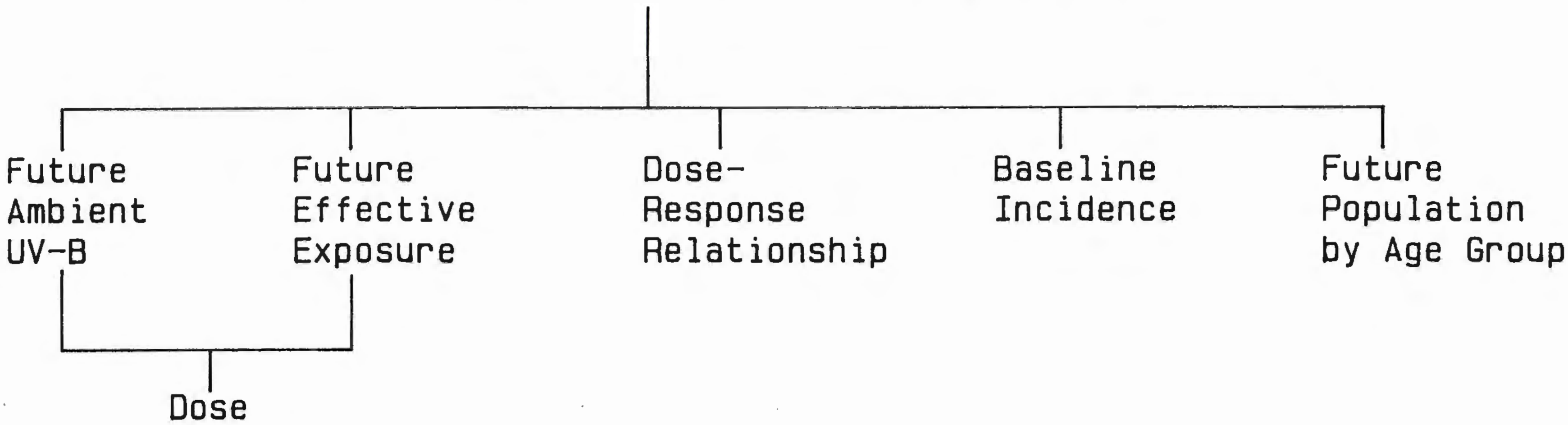



... causes are increasing affluence, changing leisure and clothing patterns, NOT ozone depletion

---

(1) Scotto, 1986
(2) Sondik et al., 1985
(3) Largest increase is in Hutchinson's melanotic freckle, which is not generally fatal and has a different etiology

# PROJECTING FUTURE SKIN CANCERS



* Dose response utilizes many forms of information

  -- case control studies
  -- animal studies (squamous)
  -- ecological studies

* Strengths of dose response relationship

  -- human data over relevant range of UV-B rather than large doses in mice to small doses in humans
  -- consistency of data and large explanatory power of data despite the fact they do not include all co-factors

* Weaknesses of dose response relationship

  -- uncertainty of action spectrum
  -- co-factors not completely represented

# FUTURE EFFECTIVE DOSE = AMBIENT UV-B x EXPOSURE

* AMBIENT UV-B DEPENDS ON OZONE LAYER

* EXPOSURE IS INCREASING

  -- boating
  -- golf
  -- tennis
  -- income

* "EDUCATION" CAN REDUCE EXPOSURE

  -- Mrs. Reagan's personal involvement
  -- Newsweek, TV, etc., every year
  -- rates of exposure may not be growing as fast
  -- Australian experience indicates limited effectiveness
  -- sun blocks lead to greater time in sun

* "EDUCATION" CAN IMPROVE TREATMENT

  -- early detection is key to treatment
  -- education increases early detection
  -- once metastasized, these are very aggressive cancers

* CURRENT PROJECTIONS FREEZE INCREASE IN EXPOSURE, WHICH IS UNLIKELY EVEN THOUGH IT HAS BEEN INCREASING

> CONCLUSIONS:
> * EFFECTIVE DOSE IS PROBABLY UNDERESTIMATED
> * OZONE DEPLETION WILL INCREASE EFFECTIVE DOSE REGARDLESS OF EXPOSURE. EVEN IF EDUCATION COULD REDUCE EXPOSURE, OZONE DEPLETION WILL INCREASE EFFECTIVE DOSE BEYOND WHAT IT OTHERWISE WOULD BE WITHOUT OZONE DEPLETION

## ASSUMPTIONS POSSIBLY LEADING TO UNDERESTIMATION OR OVERESTIMATION

* BASELINE INCIDENCE IS FROZEN IN PROJECTIONS

  -- in reality the increase in skin cancer rates has not caught up with this behavior

  -- assumes education successfully arrests increasing exposure

* AGE COMPOSITION AND SKIN COLOR ARE HELD CONSTANT

  -- as average age of U.S. population actually increases, higher rates of skin cancer will be experienced

* ACTION SPECTRUM

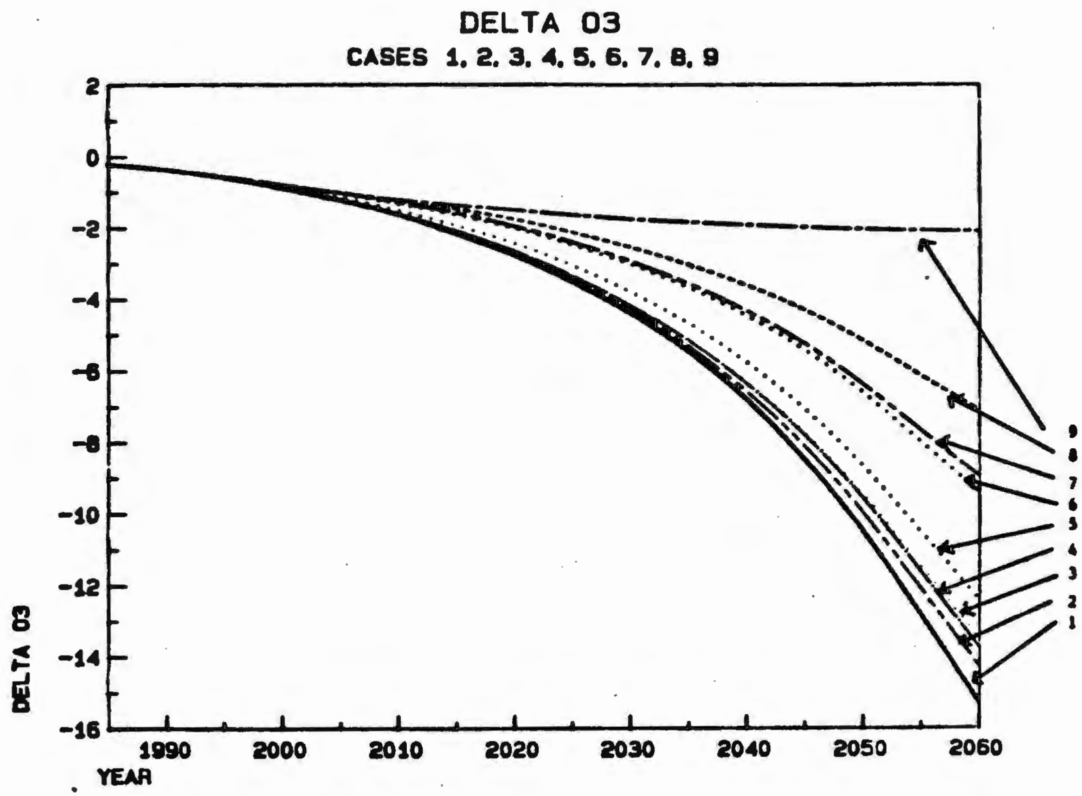
  -- DNA chosen

  -- alternative would be erethyma (~25% fewer cancers)

* MODEL USED FOR ESTIMATING OZONE DEPLETION IS LOWEST OF ALL MODELS INTERCOMPARED BY UNEP PANEL (SIMILAR TO 20% LOW)

* SURVIVAL RATES CONSTANT (NO MEDICAL ADVANCES OR NEW COFACTORS WORSENING DISEASE DEVELOP)

Comparison between a True Global Freeze and Protocol Options




Source: "Ad Hoc Scientfic Meeting to Compare Model Generated Assessments of Ozone Layer Change for Various Strategies for CFC Control, Wurzburg, Federal Republic of Germany, April 8-9, 1987"
UNEP/WG 167/INF, 10 April 1987

1. Freeze CFC-11,12. 80% compliance in developed nations. Developing nations at 20% compliance, growth to 1/4 per capita of developed nations; linear methane
2. Freeze CFC-11,12. 80% compliance in developed nations. Developing nations at 20% compliance, growth to 1/4 per capita of developed nations; compound methane
3. Freeze CFC-11,12. 100% compliance in developed nations. Developing nations at 20% compliance, growth to 1/4 per capita of developed nations; linear methane
4. Freeze CFC-11,12,113. 80% compliance in developed nations. Developing nations at 20% compliance, growth to 1/4 per capita of developed nations; linear methane
5. 25% reduction CFC-11,12,113. 80% compliance in developed nations. Developing nations at 40% compliance, growth to 1/4 per capita of developed nations; linear methane
6. 50% reduction CFC-11,12,113, Halon-1211,1301. 80% compliance in developed nations; developing nations at 40% compliance, growth to 1/4 per capita of developed nations; linear methane
7. 50% reduction CFC-11,12,113, Halon-1211,1301. 80% compliance in developed nations; developing nations at 40% compliance, growth to 1/4 per capita of developed nations; compound methane
8. 50% reduction CFC-11,12,113, Halon-1211,1301. 100% compliance in developed nations; developing nations at 40% compliance, growth to 1/4 per capita of developed nations; linear methane
9. Freeze on CFC-11,12,113, Halon-1211,1301, CFC-22, carbon tetrachloride, methyl chloroform. 100% compliance in all nations, including developing nations; linear methane

# ASSUMPTIONS USED IN PROJECTING EFFECTS OF PROTOCOL DESIGNS

FREEZE: covers CFC-11, 12, 113. Compliance rates are 100% in U.S., 80% in rest of developed world, and 20% in developing nations. Growth of non-compliers is 1/4 of baseline growth in developed nations; 3/4 of baseline growth in developing nations. In developed nations, freeze begins in 1990 at 1986 levels; for developing nations in 2000 at 2000 levels.

20% REDUCTION: covers CFC-11, 12, 113. Compliance rates are 100% in U.S., 80% in rest of developed world, and 20% in developing nations. Growth of non-compliers is 1/4 of baseline growth in developed nations; 3/4 of baseline growth in developing nations. In developed nations, freeze begins in 1990 at 1986 levels, followed by 20% reduction from 1986 levels by 1992; for developing nations freeze in 2000 at 2000 levels, followed by 20% reduction in 2000 levels by 2002.

50% REDUCTION: tested for two levels of coverage: (1) CFC-11, 12, 113, and (2) CFC-11, 12, 113, Halon-1211, 1301. Compliance rates are 100% in U.S., 80% in rest of developed world, and 50% in developing nations. Growth of non-compliers is 1/4 of baseline growth in both developed and developing nations. In developed nations, freeze begins in 1990 at 1986 levels, followed by 20% reduction from 1986 levels by 1992, and 50% reduction from 1986 levels by 1998; for developing nations freeze in 2000 at 2000 levels, followed by 20% reduction from 2000 levels by 2002, and 50% reduction from 2000 levels by 2008.

# PROJECTED AMERICAN DEATHS AVERTED

Among cohorts born before 2075

| Protocol Option Stringency | Protocol Option Coverage | Skin cancer deaths averted | Uncertainty (1) |
|---|---|---|---|
| Protocol freeze | CFC-11, 12, 113 | 947,000 | (829,000 to 1,204,000) |
| 20 percent | CFC-11, 12, 113 | 993,000 | (870,000 to 1,269,000) |
| 50 percent | CFC-11, 12, 113 | 1,072,000 | (942,000 to 1,372,000) |
| 50 percent | CFC-11, 12, 113 freeze → Halon-1211, 1301 | 1,136,000 | (1,000,000 to 1,454,000) |

Bases
Yr-2075
2+ Billion w/ Americans = projection

(1) Low end of range results from uncertainties regarding choice of action spectrum. High end of range results from uncertainties regarding choice of 1-D model used for estimating ozone depletion

# PROJECTED NON-FATAL CASES OF SKIN CANCER IN AMERICA AVERTED

Among cohorts born before 2075

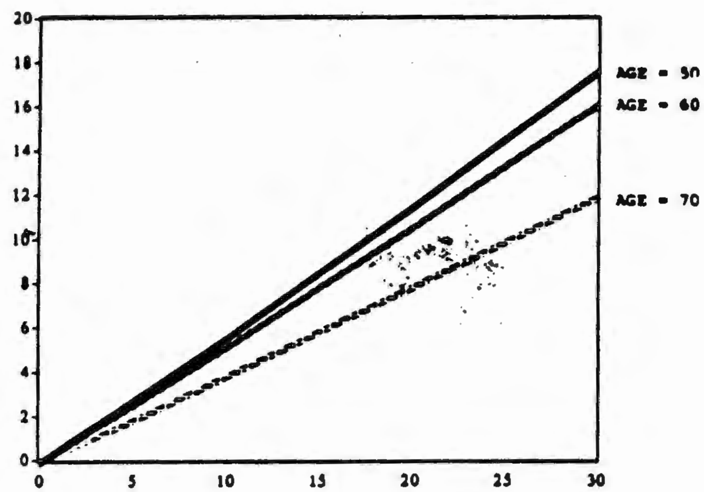
| Protocol Option Stringency | Coverage | Non-fatal skin cancer cases averted | Uncertainty (1) |
|---|---|---|---|
| Protocol freeze | CFC-11, 12, 113 | 47,920,000 | (42,454,000 to 59,923,000) |
| 20 percent | CFC-11, 12, 113 | 53,560,000 | (44,770,000 to 63,527,000) |
| 50 percent | CFC-11, 12, 113 | 54,949,000 | (48,832,000 to 69,342,000) |
| 50 percent | CFC-11, 12, 113<br>Halon-1211, 1301 | 58,609,000 | (52,156,000 to 74,024,000) |

(1) Low end of range results from uncertainties regarding choice of action spectrum. High end of range results from uncertainties regarding choice of 1-D model used for estimating ozone depletion

# CUMULATIVE EXPOSURE TO UV-B IS RELATED TO THE PREVALENCE OF SENILE CATARACTS

D-R Relatsh = for every 1% ↑ in ozone depletion, a ~3% ↑ in cataract

**Increase in Prevalence (%)**




**Increase in UV-B (% -- RB-Meter)**

**Source: Based on Hiller (1983) Analysis of NHANES Data**

* Current prevalence 9.3 million in U.S.

* Uncertainty in estimation ~ 20%

# PROJECTED CATARACTS AVERTED IN AMERICA

Among cohorts born before 2075

| Protocol Option Stringency | Coverage | Cataract cases averted | Uncertainty |
|---|---|---|---|
| Protocol freeze | CFC-11, 12, 113 | 12,455,000 | (+ or - 20%) |
| 20 percent | CFC-11, 12, 113 | 13,332,000 | (+ or - 20%) |
| 50 percent | CFC-11, 12, 113 | 14,917,000 | (+ or - 20%) |
| 50 percent | CFC-11, 12, 113 Halon-1211, 1301 | 16,323,000 | (+ or - 20%) |