



The shape of war to come?

Unless we seek to ban such research now, it is almost certain that military scientists around the world will perfect methods for harnessing the forces of the geophysical environment for waging war. the *SIPRI Yearbook*, published today, spells out some of the awesome possibilities

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Six months ago, *New Scientist* (vol 69, p 6) carried a cover story about the threat of environmental warfare. In it, Dr Frank Barnaby,

Director of the Stockholm International Peace Research Institute (SIPRI), argued that there were two different impacts on the environment caused by war: the damage done during the fighting, either deliberately or incidentally; and the use of artificial changes in the environment as an actual method of warfare. Barnaby pointed out that though there is increasing concern for both of these phenomena, "the former is considerably more real than the latter." At the top of his list he put the use of herbicides and strategic bombing.

Now, in this year's issue of the *SIPRI Yearbook*, more detail is given about the actual techniques being investigated for modifying the weather, the ionosphere, the oceans, and for triggering earthquakes as a means of inflicting death and destruction on an enemy. As the SIPRI scientists point out, until about a decade ago, interest in these topics was directed purely towards their peaceful application, "but a considerable amount of research has been carried out recently into the use of methods of weather and climate modification as weapons of war."

Weather modification does not simply consist of altering the rainfall pattern alone. It also includes modification of fog, hail, severe storms, cloud electricity, and lightning. Fog, for instance, is formed when moist air is cooled. As the humidity approaches saturation point, small droplets of water begin to obscure visibility. This immediately suggests a means for producing fog artificially. If heat, for instance, is removed from the atmosphere, the humidity of the air will be raised to near saturation. However, this method requires large amounts of energy and is cumbersome. But, notes the *SIPRI Yearbook*, where the relative humidity is well below 100 per cent, fog could be produced using hygroscopic seeding materials. Because of their affinity for water vapour, the hygroscopic particles would initiate condensation. Even so, in both these methods, the chance of fog formation would depend very much on local wind conditions.

Six months ago, Barnaby suggested that it was perhaps the success of Soviet experiments on modifying hail clouds for peaceful purposes that made them interested in seeking a bilateral prohibition on environmental weapons with the United States. Academician E. K. Fyodorov, director of the Institute of Applied Geophysics of the Soviet

Academy of Sciences and government adviser on environmental warfare, claimed that use of anti-aircraft guns and missiles firing explosives and materials for stimulating crystallisation of supercooled drops could help reduce the damaging effects of hail on crops by factor of four or five.

In the case of lightning modification, the Stockholm-based researchers note that though it has been suggested as a means of tactical warfare, it is simply not feasible at present—because the mechanism of lightning itself is poorly understood. "The limited frequency and extent of thunderstorms also makes lightning modification a very dubious weapon of war." However, one method of modifying lightning strikes, based on sudden perturbation of the electric field, seems to have had some success. "A method based on this principle has been used," says the *Yearbook*, "in which lightning is triggered artificially by launching small rockets carrying a thin steel wire, one end of which is connected to the ground."

Turning to the modification of hurricanes, the group points out that there are two key factors involved here. First, the transfer of latent heat from the sea surface to the air inside the storm is essential if a hurricane is to reach and retain significant intensity. The second feature is that the energy of the hurricane is released by convection in highly organised convection cell circulations. "Theoretically," says the study group, "it is possible to use hurricanes and other storms as weapons by enhancing, dissipating or guiding them by means of cloud seeding or other techniques. A controlled hurricane could be used against a country with an extensive coastline."

In order to generate a hurricane, heat transfer from the sea to the atmosphere is essential. Thus the evaporation from large areas of water could be modified by spreading thin layers of oil over the surface. "This technique, together with cloud seeding, could in theory be used to guide a hurricane to destroy enemy coastal defences." It must be emphasised, however, that the use of such phenomena as weapons is still highly speculative.

Tampering with the climate

Modification of the climate could be brought about mainly through changes in the radiative and thermal budgets of the atmosphere—by the introduction of aerosols, for instance. And the temperature of the atmosphere itself could be changed by altering the reflectivity of the Earth's surface by, say, covering regions with soot or asphalt.

One important method suggested for modifying atmos-

pheric processes is the suppression of evaporation from lakes and reservoirs. This could be achieved easily by spreading a thin film of oil (monomolecular layer) on the surface of the water. (The evaporation from water surfaces is thought to depend on wind shear rather than on wind velocity. Thus suppression of evaporation in this way would seem really to be due to the effects of the oil monolayer on diffusion and convection rather than on vaporisation.)

"Modification of climate is on the whole still in the realms of theoretical possibility," says the SIPRI study, "but it is envisaged as a strategic weapon which could, for example, be used to destroy the enemy's agricultural pattern . . . It is thought that it may not be possible to achieve such changes in large scale atmospheric circulation in the coming two or three decades."

While the properties of the atmosphere itself are not particularly well understood, the mechanisms that drive the oceans and earthquakes too are even less understood. But there are phenomena, such as tsunamis, which are well documented. These extremely violent tidal waves often result when sediments and rocks perched on the continental shelf slide suddenly into the ocean deep. They can even occur as a result of earthquakes. "A series of phased explosions could be used to create such movements," suggest the Stockholm group. Another method of launching tsunamis might be to use nuclear explosions—either underwater or along the base of large ice sheets, causing them to slide outwards into the water. "If large ice velocities are achieved," comments the report, "this could create tsunamis causing enormous damage to coastal regions."

As far as earthquakes are concerned, there appear to be two principal methods for triggering events artificially. The first is by using explosions powerful enough to shake the ground in large areas and thereby trigger strain-relieving movements of the crustal material. In the second method, the strain energy is released by pumping in water, which acts as a lubricant and causes adjacent blocks of rocks to slip. (A series of small earthquakes were detected when liquid wastes were pumped underground near Denver.)

The report points out that the water technique for triggering an earthquake is rather clumsy and easily detectable. "On the other hand," it notes, "if the strain pattern of the region is accurately known, it may be theoretically possible to release the strain and cause an earthquake in that region by remotely placed, phased, or timed explosions." According to the modern theory of plate tectonics, however, this would seem to restrict earthquake modification as a weapon to certain parts of the earth—making it rather unlikely to be used as a means of warfare.

But perhaps the most exotic form of geophysical warfare concerns tampering with the electrical behaviour of the ionosphere, that ionised region of the atmosphere which extends from 50 km or so up to hundreds of kilometres above the surface of the Earth. Techniques for disturbing radio communication by "punching holes" in the ionosphere with nuclear explosions have long been discussed. So, too, have proposals for opening up lethal windows in the ionosphere to let in the short wavelength ultraviolet radiation (less than 300 nm) which is known to damage biological systems, causing skin cancers in man and damage to crops.

What is new is the suggestion that the natural wave-guide between the ionosphere and the Earth could be used to propagate very low frequency (VLF) radiation through it in such a way as to affect the electrical behaviour of individuals' own brain activity. The alpha activity of the brain is characterised by rhythms with a frequency of around 5 Hz, which is rather close to the lowest resonant frequency, 8 Hz, of the ionospheric wave-guide. This type of radiation is difficult to detect because of its long wavelength.

Very little is known at present about the effects of weak

oscillating fields on human behaviour. In some experiments the field strength used was around a few hundredths of a volt per centimetre, and the result of exposing human subjects to such fields for 15 minutes or so showed a small but measurable deterioration in the person's performance. Such fields, however, were a thousand times greater than the observed natural oscillations in the Earth's wave-guide. The SIPRI Yearbook comments: "If methods could be devised to produce greater field strengths of such low frequency oscillations, either by natural (for example, lightning) or artificial means, then it might become hypothetically possible to impair the performance of a large group of people in selected regions over extended periods."

Really, the most disturbing aspect of geophysical modification is that such operations could actually be carried out quite covertly. A state could seed clouds over its own territory, for instance, knowing full well that this would cause changes in the rainfall or snowfall pattern over a neighbouring country. And the state downwind might simply attribute such changes to natural fluctuation. "A more serious aspect of the development of geophysical warfare is that the threat to peace may not only come from actual use of such techniques, but from the fears and perceptions which states may develop about what others could be doing to them by the use of such techniques," says the Yearbook. "It may become possible to blame, rightly or wrongly, adverse changes in one's own weather, climate or other conditions on others."

Clearly, the prospect for gross interference with the weather or climate for military purposes is so disturbing to most people that the SIPRI scientists believe there would be massive support for a universal ban on geophysical weapons—"even more so because, unless banned, these weapons will almost certainly be developed."

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