6) It has its roots in earlier U.N. resolutions introduced by the United States for the peaceful uses of outer space.

7) The Congress, by resolution, has indicated its interest in it as a national goal.

For these reasons, I urge that it be made a vital element of this nation's post-Apollo efforts in space.

Through Space, a Better World

The greatest thrill I can imagine for myself is to stand on the moon's surface and to look back from the harshness of the lunar landscape to the luminous hospitable earth. From that vantage point, I believe, I could view the earth in its oneness. There I could better understand that indeed all mankind properly shares in the pride of attaining a lunar landing. After all, it is science and engineering, the common heritage of all mankind, that made it possible! All nations and races have contributed to the unbroken threads of knowledge that comprise science.

From space, the earth must indeed appear a rare and beautiful place in the vastness of the universe. I sometimes gain this sense of the emptiness and scale of the cosmos when I fly my plane over the lightless reaches of western Nevada on a dark, clear night and see the Galaxy stretched out overhead.

The past steps in space have required extraordinary bravery and emotional stability on the part of the men of our space program, who understood, as the public only vaguely does, the hazards of the task. To take the next great step in space will require no less skill and knowledge, equally steadfast courage, and a parallel sense for innovation. The next step in space must be directed toward the earth. We must turn our newly discovered skills toward the construction of world systems that make the planet earth even better than it is now for its burgeoning numbers of people. We must invent new world-technologies. We must commit the resources of space science, directly and indirectly, to the achievement of an optimum balance of man and nature on this magnificent but imperiled planet.

Reference

1. *Useful Applications of Earth-Oriented Satellites* (National Academy of Sciences, Washington, D.C., 1969).

Meteorology and the Supersonic Transport

Research in stratospheric meteorology has significance for future operations of the supersonic transport.

Frederick G. Finger and Raymond M. McInturff

The proposed supersonic transport (SST) should bring about great changes in commercial aviation—changes at least as radical as those which resulted from the inauguration of subsonic jet aircraft. Cruising speeds of the initial supersonic transports will be two to three times faster (up to about Mach 2.7) than those of today's airliners, and ceilings for needed meteorological data will be nearly twice as high (up to about 20 kilometers). Two different designs of SST, the Anglo-French Concorde and the Russian TU-144, are currently being flight-tested; the U.S. version is in the design stage.

Since meteorological support to commercial aviation is necessarily tailored to the characteristic flight levels of the various types of aircraft in use, information on stratospheric levels (see Fig. 1 for accepted definitions of atmospheric layers between 0 and 22 kilometers), will, for the first time, be needed for routine civil-aviation operations. At present, data from heights up to about 12 kilometers provide the basis for all meteorological operations—public forecasts, aviation forecasts, and so on. These data are obtained from the vast network of surface observational sites and the more than 800 upper-air stations, most of which regularly take balloon-borne radiosonde observations of temperature, wind, and humidity twice daily (*1*).

Only recently have meteorologists begun to receive sufficient stratospheric data, mostly from the Northern Hemisphere, to conduct intensive research for these high altitudes. Even though current operations do not require data above 12 kilometers, there has been a concerted effort on the part of all nations to provide meteorological data to the greatest possible heights. This effort is being aided by technological advances, most notably in balloon fabrication. The greatest progress has taken place in anticipation of special scientific periods, such as the International Geophysical Year, 1957–58 (*2*) and the International Years of the Quiet Sun, 1964–65 (*3*).

The improvements in the upper-air observing network have had an obvious effect, but stratospheric data are still sparse and relatively inaccurate as compared with tropospheric data. For example, less than half of the total number of stations supply data above 16 kilometers for any given observational time. Moreover, data coverage is far less complete in the Southern Hemisphere than in the Northern. Despite the paucity of measurements and the perhaps more serious problem of inaccuracies within the data that are available, our knowledge of the higher atmosphere is rapidly increasing.

In this article we review the significant atmospheric phenomena that may affect either the safety in flight, or the economics, of the SST aircraft. Reference is made to the general nature of the meteorological support that will be required for operations. A prominent

The authors are affiliated with the Environmental Science Services Administration, Weather Bureau. Mr. Finger is chief of the Upper Air Branch of the National Meteorological Center, Hillcrest Heights, Maryland; Mr. McInturff is a research meteorologist in the same branch.

question is whether we yet have sufficient knowledge of the higher atmospheric layers and sufficient instrumental accuracy to provide the needed operational support.

Storms and Turbulence

Although the SST will operate primarily in the stratosphere, a portion of its flight time will necessarily be spent at lower levels. For example, on a flight from New York to London, an estimated one-third of the 2½-hour flight time would be spent below the cruising level (*4*)—in takeoff, subsonic climb, transonic acceleration and deceleration, descent, and landing.

During the various phases of subsonic flight which will occur at tropospheric levels, the SST will probably require the same information that is afforded contemporary subsonic aircraft. The possibility that this aircraft will be given priority treatment even while it is operating in a subsonic mode has been a matter of debate; informed statements have indicated that air traffic control procedures will not permit this. Thus, there is no reason to expect significant augmentation of meteorological support to the SST for its subsonic mode.

In contrast to the subsonic portion of the flight, there is little doubt that special meteorological forecasts will have to be available within the transonic corridors (where the aircraft will accelerate from subsonic to supersonic speeds or will decelerate from supersonic to subsonic speeds). Under planned conditions, supersonic speeds will be attained below cruising altitude, in the layer from about 9 to 16 kilometers. Thus the SST will begin acceleration near the highest level of present-day jet operations. At this stage it will be mandatory that certain weather conditions which might prove hazardous be avoided—such as hail-producing thunderstorms and the severe turbulence usually associated with convective clouds.

Climatological records indicate that the probability that thunderstorm activity will occur decreases with height above 3 kilometers; that is, horizontal storm-coverage tends to decrease with height above that altitude. Thus, the higher the altitude at which transonic acceleration takes place, the lower the probability that the aircraft will encounter precipitation and convective-type turbulence. Even so, a significant number of thunderstorms, in fact the most severe ones, reach upper tropospheric and lower stratospheric levels. These storms occur most frequently in the tropics, but also in other regions. One such area, the so-called "tornado belt" in the south-central United States, has been the subject of numerous studies (*5*).

Recent observations indicate that severe storms may extend above the 18-kilometer level (*6*). In fact, the mean height of one large observational sample was found to be 14 kilometers, which is within the proposed limits of the SST transonic corridors. Results of another study (*7*) are summarized in Fig. 2, which shows, for various regions and months, what percentage of the time echoes are likely to be received by ground-based radar from clouds at least 15 kilometers high. Figure 2 may be interpreted as a probability diagram, the probabilities for the various locations being shown as functions of months. For example, at New Orleans, one of the most active thunderstorm areas, it may be expected that precipitation echoes will be received from heights of 15 kilometers or more 13 percent of the time during the month of July.

Long-range airborne radar, capable of detecting thunderstorms at a distance of several hundred kilometers, will be a necessary part of SST equipment. However, unplanned diversionary procedures may prove costly in terms of fuel consumption and passenger inconvenience. Therefore, weather phenomena within the transonic region will have to be located and carefully predicted prior to takeoff so that any avoidance procedures can be included, insofar as possible, as an integral part of the flight pattern.

At present, the most reliable instrument for determining the height, location, and movement of thunderstorms is ground-based radar. But radar observations are necessarily limited in

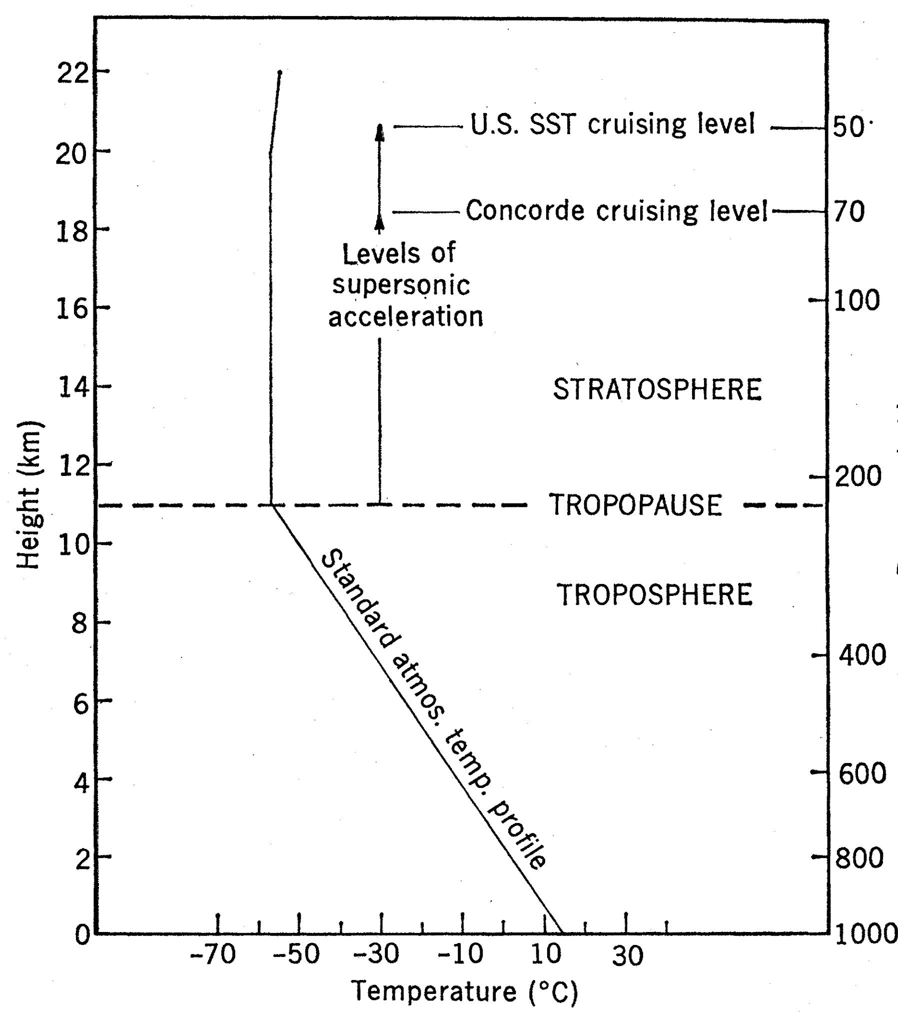

Fig. 1. Vertical distribution of temperature up to 22 kilometers, according to the *U.S. Standard Atmosphere, 1962* (see *15*); common nomenclature for the two lowest atmospheric layers and the boundary which separates them; and probable upper levels of SST flight.

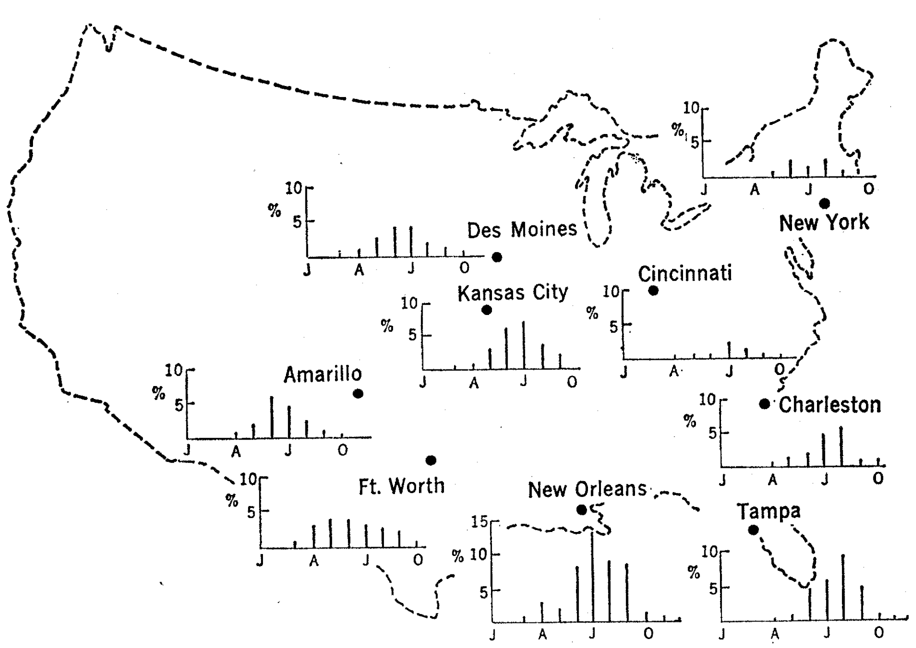

Fig. 2. Monthly probabilities (in percentages) that precipitation echoes will be received from heights of 15 kilometers or more in various parts of the United States, based on data obtained between 1962 and 1967 (see *7*); *J, A, J, O* refer to January, April, July, and October, respectively.

number because of the high cost of equipment and operating personnel. Much reliance is still placed on more or less subjective judgments of observers on the ground or in aircraft.

The prospect of using meteorological satellites for certain phases of observation is becoming increasingly attractive. At present, meteorologists are striving to make full operational use of the information received from the latest polar-orbiting weather satellite of the Environmental Science Services Administration's ESSA series (*8*). Cloud data from on-board photographic equipment are being used to supplement data received from the worldwide synoptic network. Another vehicle of great potentiality is the Applications Technology Satellite (ATS) (*9*). This "geostationary satellite," so-called because its angular velocity matches that of the earth, is positioned approximately 37,000 kilometers above the earth and is capable of providing, within 25-minute intervals, extremely clear photographs of clouds over low and middle latitudes on the sunlit side of the earth.

Figure 3 shows how the ATS may be used. In the photograph (left) taken at 1030 EST, a typical extratropical cyclone, just beginning to occlude, is shown centered in the Great Lakes region. A relatively cloud-free area appears (south of the arrow) in the warm sector between the cold front and the warm front. The photograph taken only 3 hours later (top right) discloses a squall line (indicated by the dot-dash line in the inset drawing) which had developed in the warm sector ahead of the cold front. By 1530 EST (bottom photograph) the squall line had reached a mature stage and, according to independent observations, contained some severe thunderstorms and tornadoes. The numerous photographs taken between the times of these three made it possible to watch this potentially dangerous line of storms on a nearly continuous basis. Obviously, the potential value of this system goes well beyond the support of SST operations.

A major limitation of these present-day ATS photographs is the fact that they are necessarily restricted to the daylight portion of the earth. However, other methods can be used for detecting nighttime cloud cover. One involves the use of radiometers to measure infrared radiation from the clouds and earth. In a more recent development, starlight would be used in photographing the earth-cloud system (*10*).

Clear air turbulence (CAT) may occur with little or no warning in the troposphere, since at present there are no fully reliable methods for predicting it. Research on this subject is continuing, but the meteorologist has lacked accurate data. Much of the information on CAT is in the form of pilot reports, which are necessarily subjective. Work has been done to correlate these reports of turbulence with reported temperatures and winds from radiosonde observations. However, turbulence is a local or small-scale phenomenon and can hardly be defined by the relatively coarse grid of the present-day upper-air network. Moreover, the temperature-versus-height curves derived from radiosonde observations are necessarily smoothed to facilitate dissemination, and this smoothing tends to obscure small-scale atmospheric perturbations.

Despite major problems, much has been learned about turbulence. For example, the effect of mountains on airflow ("mountain-wave turbulence") is fairly well known. Even more important is the increasing knowledge of the relationship between jet streams and turbulence. All the available information is now being utilized as input for regular turbulence forecasts, at present issued for heights reached in subsonic jet flight.

Recent observations obtained at heights of 14 to 21 kilometers in conjunction with the U.S. Air Force's high-altitude clear air turbulence (HICAT) program (*11*) indicate that clear air turbulence does occur at stratospheric levels, most frequently between 15 and 17 kilometers—slightly below the lowest proposed SST cruising level. Moreover, HICAT has been found over all types of terrain and at all latitudes, although there appear to be seasonal variations in frequency. Studies generally classify the intensity in categories ranging from very light to severe. However, reported intensity is in part a function of aircraft response, and different aircraft respond in different ways. Most measurements of turbulence at high altitudes have been achieved with U-2 aircraft. Although these aircraft are quite different from the SST in weight, configuration, and speed, they provide data which, with the aid of certain transfer functions, can be used to estimate probable turbulence effects on the SST.

The probability that an accurate CAT forecasting system will be developed is rather low, especially for stratospheric levels, owing to the various unsolved problems associated with the present-day observational network. The possibility of utilizing on-board turbulence-detection equipment as a substitute is being investigated. This equipment must have sufficient range to allow the pilot time to circumvent areas of turbulence while traveling at supersonic speeds. Laser is one of the techniques now being considered.

Wind and Temperature

We now have a fairly good knowledge of the gross features of the wind and temperature fields in the layer between 12 and 30 kilometers. Analyses of those fields are being made by several groups, but up to this point mainly for purposes of research (*12*).

Wind data will be necessary for SST operations since, with any aircraft, wind causes measurable variations in ground speed and thus in time en route. Accurate forecasting of wind fields along routes flown by present-day jets is important, since these airplanes may be airborne for more than 10 hours at a time. The SST, on the other hand, will fly two to three times faster, and on comparable routes will be airborne only one-half to one-third as long. Therefore, the influence of winds will be proportionately less, provided wind speeds at proposed SST cruising levels are not significantly greater than wind speeds at flight levels of subsonic jets.

While westerly winds prevail throughout much of the troposphere regardless of season, this is not the case for the major portion of the stratosphere. It has been known for some time that most of the stratosphere (from about 18 to 55 kilometers) has what may be termed a monsoonal-type circulation pattern. This pattern is characterized by extremely stable easterly flow in summer and more variable but generally stronger westerly flow in winter (*13*). Transition periods, when winds are usually light and variable, occur during spring and autumn. Mean wind speeds associated with the lower boundary of the stratospheric circulation (at about 17 to 20 kilometers) are generally lower than mean wind speeds in the upper troposphere (at about 12 to 15 kilometers), as may be seen from the data of Table 1.

Table 1. Mean wind speeds at the 20-kilometer (50-millibar) and 12-kilometer (200-millibar) levels and mean 24-hour wind variabilities (root-mean-square changes) at the 20-kilometer level for January and July, on the basis of data for a 5-year period (*13*).

Latitude band	Wind speed (m/sec)		24-hour variability at 20 km (m/sec)
	20 km	12 km	
	January		
20°–30°N	6	25	8
30°–40°N	9	30	7
40°–50°N	14	25	8
50°–60°N	14	16	9
60°–70°N	15	11	9
70°–80°N	19	6	11
	July		
20°–30°N	16	4	5
30°–40°N	9	11	4
40°–50°N	4	20	5
50°–60°N	3	15	4
60°–70°N	3	7	4
70°–80°N	2	4	3

It is fortunate that the initial SST's will operate at stratospheric levels where winds are weakest. Light winds are by no means characteristic of this entire atmospheric layer; for example, speeds approaching 100 meters per second are common at 30 kilometers. Indeed, several instances of speeds approaching 200 meters per second have been reported between 45 and 50 kilometers. Therefore, winds may prove to be an important factor for second- or third-generation SST's, which will probably operate at higher altitudes.

Even though the data indicate that winds at cruising levels should pose no unique flight problems, a knowledge of the wind field will certainly be important for the economics of operations. This importance may be reflected in the form of trade-offs between fuel reserves and passengers or cargo. Preliminary requirements indicate that winds will have to be known to within a vector error of less than 7 to 10 meters per second, the error being a mean value over a 1000-kilometer route segment (*14*).

What type of forecasting system will be needed to satisfy these requirements? More precisely, will "persistence" (reliance on charts analyzed as long as 24 hours in advance of flight) be sufficient, or will it be necessary to produce, 24 hours in advance, forecasts of the wind based on the equations of atmospheric motion? An indication of how well persistence would serve as a forecast is given by the mean wind variability near cruising level (50 millibars, or 20 kilometers) shown in Table 1. The 24-

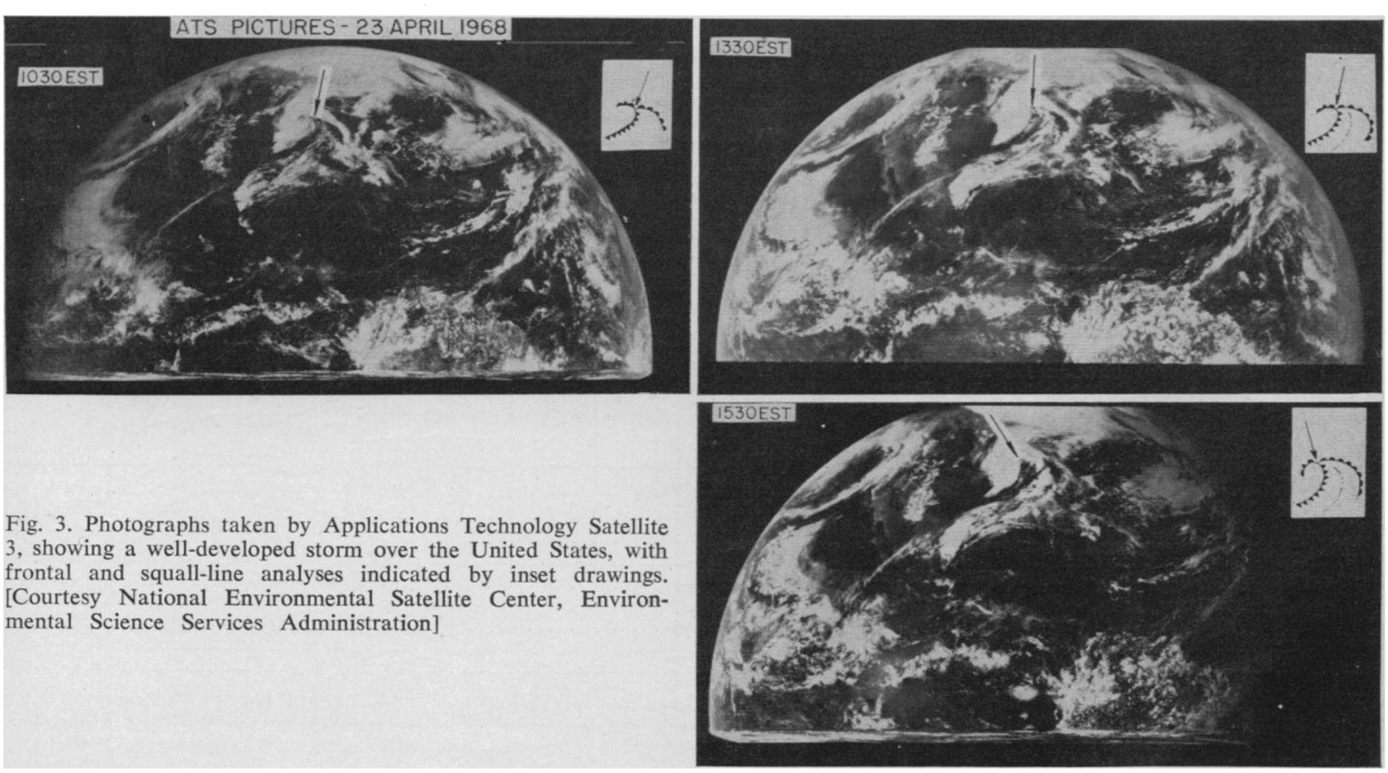

Fig. 3. Photographs taken by Applications Technology Satellite 3, showing a well-developed storm over the United States, with frontal and squall-line analyses indicated by inset drawings. [Courtesy National Environmental Satellite Center, Environmental Science Services Administration]

hour vector changes for July are below the error limit of 7 to 10 meters per second, and persistence will undoubtedly serve as a useful forecast tool. However, in winter, especially at high latitudes, the variations are significantly greater. Thus, methods based on principles of atmospheric dynamics may be required during this season.

According to present designs, the SST will be adversely affected by relatively high atmospheric temperatures (for various reasons, including reduction of thrust, possible decrease in tensile strength of some metals, and limitation of the engine intake). The temperature at transonic levels will probably be of greatest concern, owing to the thrust requirement.

The phrase "relatively high temperatures" has meaning only when the design criteria of the aircraft are considered, since an assumed ambient air temperature is used in computing performance characteristics. The temperature profile (Fig. 1) most often used for this purpose (as well as for many other applications) is that of the "standard atmosphere" (*15*). This hypothetical reference atmosphere is based on climatological information and is generally representative of mean mid-latitude conditions. Thus, "relatively high temperatures" are temperatures that are higher than standard. In the layer between 12 and 20 kilometers (which includes most of the probable transonic acceleration and cruising levels), the standard atmospheric temperature is approximately −56°C.

Mean-temperature information for North America at both the 12-kilometer (200-millibar) and 20-kilometer (50-millibar) levels indicates that the standard-atmosphere temperature is generally exceeded during July, the peak of the summer season. The deviations are greater than 10°C in Arctic regions. January mean-temperature fields are more complex. While summertime values appear to depend on latitude only, and are probably valid for the entire hemisphere, wintertime values indicate variation with both latitude and longitude. Figure 4 reveals relatively high temperatures centered in the Siberia-Alaska region, which are characteristic of that area and are associated with the so-called Aleutian stratospheric anticyclone.

It is expected that temperatures averaged over 1000-kilometer route segments at cruising level will have to be known to within at least 3°C (*14*). Variability of temperature at both the transonic and cruising levels is now being studied in order to determine whether persistence will suffice as the basis for forecasting, or whether the system based on atmospheric dynamics, now used for tropospheric levels only, will have to be used for stratospheric levels as well. Figure 5 shows some of the results of a recent study of temperature variability at flight levels of subsonic jets and at cruising levels proposed for the SST. It is evident, even though the period of record is short, that the

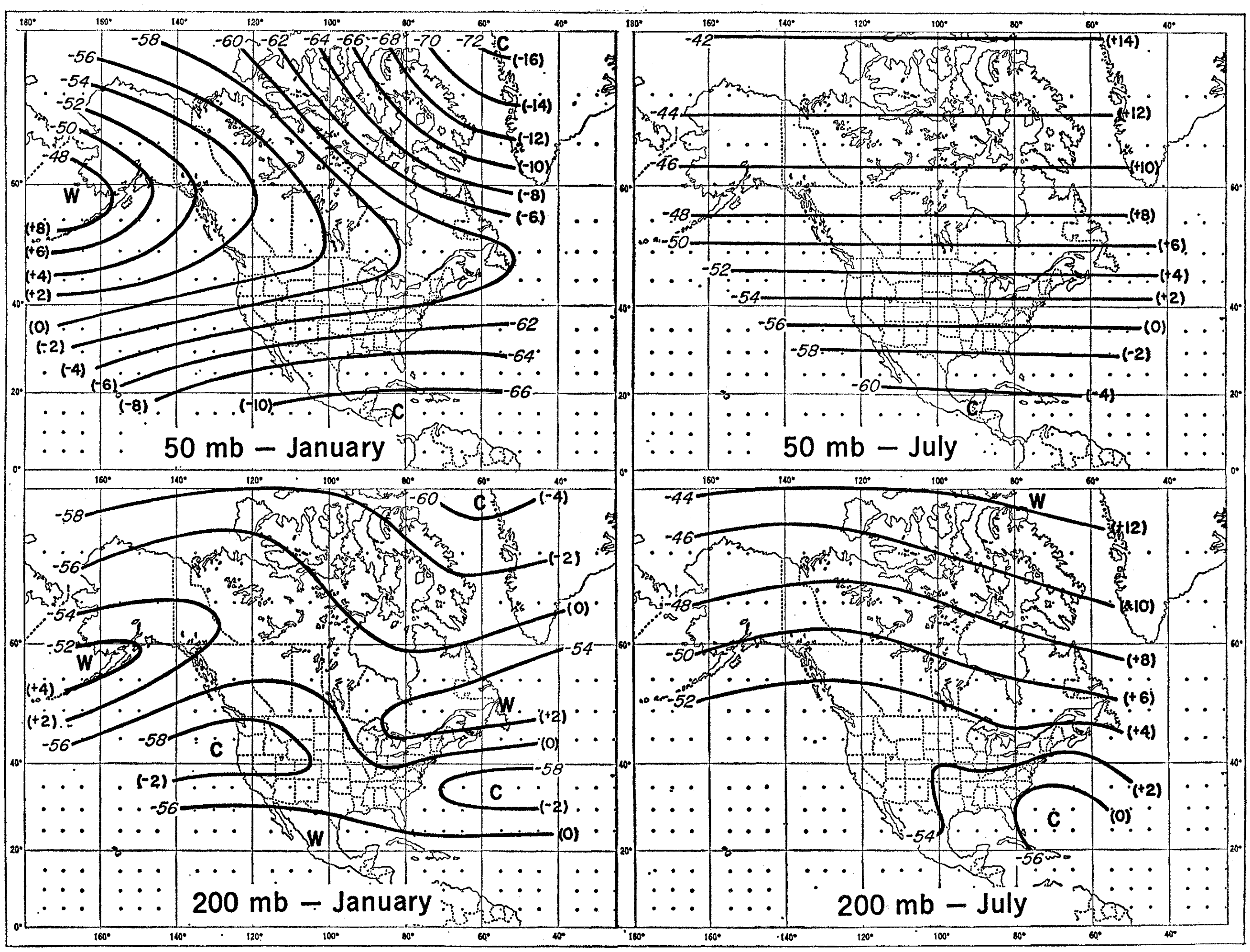

Fig. 4. Maps of mean temperatures over North America at the 50-millibar (20-kilometer) and 200-millibar (12-kilometer) levels. Each isotherm is labeled in degrees Celsius (for example, −54) at one end, and in terms of departure from the Standard Atmosphere Temperature (for example, +2) at the other end.

variability is relatively small at the higher altitudes. Only during one particular winter at the very northernmost latitudes are values for the higher level greater than those for the lower level.

While statistical results indicate that variabilities in wind and in temperature are smaller at cruising levels proposed for the SST than at cruising levels of present-day subsonic jets, one still must consider instances where relatively large changes occur at the higher altitudes. Even if they are infrequent, it will be necessary to predict them. The phenomenon responsible for much of the wintertime stratospheric variability is the so-called sudden or explosive warming. Conditions during warming episodes have been documented many times; it was the discovery of one such event (*16*) in 1952 that stimulated renewed interest in exploring conditions in the higher regions of the atmosphere.

Major stratospheric warming events, resulting in enormous and rapid temperature changes and in complete disruption of the normal wintertime westerly flow, have occurred only five times in the past 17 years (*17*). During the recent event of January 1968, temperatures rose more than 30°C at the 20-kilometer level over a large area at northern latitudes during a 4-day period (*18*). This is certainly a significant change, but even greater variations have taken place at higher altitudes. For example, temperature rises of more than 50°C near the 30-kilometer level, occurring over a period of a few days, have been observed; these are equal to or greater than record increases at ground level.

Analysis of data obtained by meteorological rocketsondes (*19*) indicate that changes of still greater magnitude occur at altitudes up to at least 55 kilometers. It has also been shown that these events can first be detected at altitudes greater than 40 kilometers, and that they descend to lower stratospheric altitudes with time. Much speculation has arisen over the possible relationships between this stratospheric phenomenon and tropospheric weather. Certainly the collection of more data in support of SST operations will facilitate a greater research effort toward discovering stratospheric-tropospheric relationships.

In view of the significant probability that major stratospheric warmings will occur during one out of every three or four winters, and the near-certainty that less intense but significant changes will take place every winter, it is concluded that some method other than persistence will be necessary for forecasting conditions at SST cruising levels. The most successful forecasting method developed to date is based on the fundamental equations of atmospheric motion; it is now used operationally for heights up to 12 kilometers (*20*). Preliminary work on testing the applicability of this model at heights up to 20 kilometers has already begun.

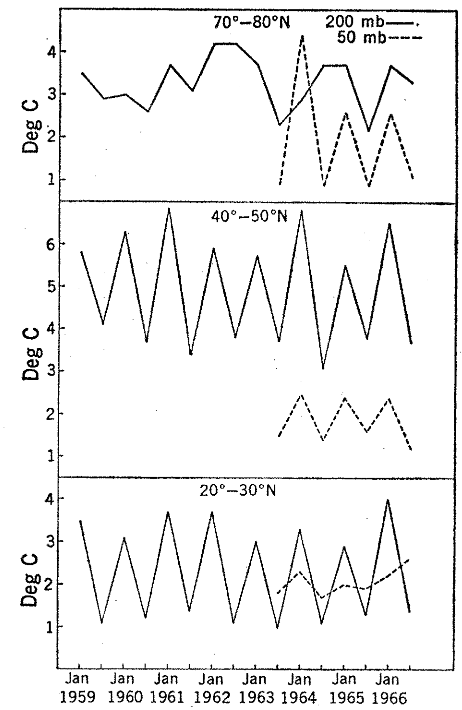

Fig. 5. Twenty-four-hour root-mean-square temperature changes between 1959 and 1966 at 50 millibars (20 kilometers) and at 200 millibars (12 kilometers) averaged over three latitude bands of North America: 20° to 30°N, 40° to 50°N, and 70° to 80°N (see *41*).

There are several problems associated with the development of a forecasting system for the stratospheric levels. One such problem is that of ozone distribution. This allotrope of oxygen plays an important role in the radiation balance of the stratosphere, and therefore information on its distribution is crucial to determination of the thermal field. More fundamental, however, is the problem of instrumental accuracy at high altitudes. Unfortunately, there is uncertainty about the accuracy with which the radiosonde instruments of different types now used throughout the world can measure temperature above 16 kilometers. This uncertainty is not surprising since a number of the instrument types in use today were designed some years ago and primarily for the purpose of measuring tropospheric temperature.

The major difficulty with several of the instrument types lies in the radiation error of the thermistor, especially in the presence of sunlight. As a result of this error, temperature measurements obtained during daylight hours at the proposed SST cruising levels may be 5° or 6°C too high. Several studies have been made to consider this problem (*21*), and correction systems have been devised for application to measured data at the observation point. Regrettably, correction procedures have not been devised for all the different instrument types, and many of the instruments in use do not yield the desired accuracies. This problem has forced the analyst to devise his own correction schemes, which are applied to meteorological stratospheric data just prior to the analysis of high-altitude charts (*22*). Only after such correction are the charts fairly accurate representations of the atmosphere. While much of the burden of applying corrections has hitherto fallen on the data analyst, most meteorological services throughout the world are now aware that problems do exist. Several are in the process of redesigning instruments in the hope of increasing their accuracy.

The evaluation of mesoscale temperature variations at stratospheric levels has received considerable attention in recent years, since a few aircraft observations have indicated changes of 10°C or more over distances of a very few kilometers. Routine observations made at 12-hour intervals from our worldwide meteorological network are much too sparse, temporally and spatially, to confirm these scattered reports. Results of special programs of frequent observations from a network observing mesoscale variations indicate that root-mean-square temperature changes over periods of 6 hours and less have maximum values at transonic phase levels—that is, near 12 kilometers (*23*). Thus it may be seen that the greatest variability occurs precisely where the aircraft will be most sensitive to fluctuations in temperature. Further research will probably require a number of radiosonde observations closely spaced with respect to both time and distance, or a large number of high-altitude temperature measurements from aircraft, or both. Reports from operating SST aircraft may ultimately be our best source of information in this important area, if problems of instrumental accuracy can be solved.

Even with a much denser worldwide radiosonde network than we have now, there would still be observational deficiencies, both in the stratosphere and in the troposphere. Thus it is only natural to look for remote sensing methods to replace the *in situ* type of atmospheric sounding provided by the radiosonde. With the launching of the Nimbus III meteorological satellite on 14 April 1969, we achieved a breakthrough in this area. The satellite infrared spectrometer (SIRS) aboard this spacecraft measures infrared radiation in seven wavelength intervals of the carbon dioxide absorption band at 15 microns and in the water vapor widow at wavelengths from 8 to 12 microns. From these measurements we can compute the vertical distribution of atmospheric temperature from the earth's surface, or from cloud tops, at least up to 30 kilometers, over the entire globe (*24*). Data have thus become available from vast areas which hitherto have not been accessible to meteorological observation, and they aid enormously in synoptic analysis. Figure 6 is an example of a radiance field, one of several from which temperatures and heights of isobaric surfaces in the stratosphere have been derived by statistical regression techniques (*25*). This is the first in a series of maps used in 1969 to study the minor midwinter warmings which occurred in the Southern Hemisphere stratosphere, by following the changes in the patterns of high and low radiances (corresponding to high and low temperatures, respectively). In this case, the radiances characterized a deep stratospheric layer centered near 24 kilometers (*26*). Similar maps will undoubtedly be used for the first time in detecting and tracking warmings over the Northern Hemisphere during the winter of 1969–70.

With continued increase in the resolving power of infrared spectrometers, it may soon be possible to determine mean temperatures of areas less than 10 kilometers in diameter. The final goal of all this work, of course, is the continuous measurement of temperature throughout the entire earth's atmosphere, and this goal seems to be well within our reach in the foreseeable future.

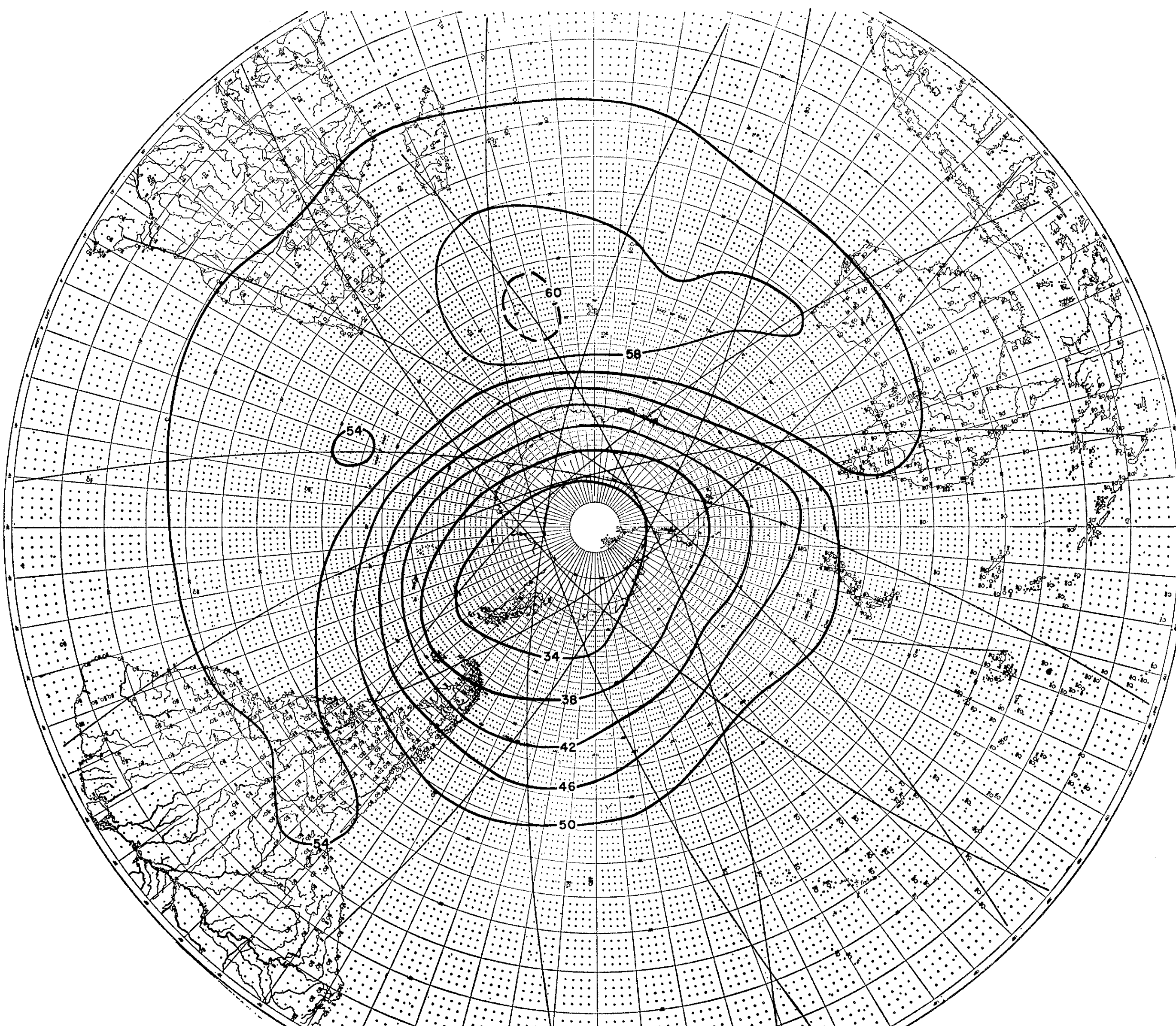

Fig. 6. Field of radiances over the Southern Hemisphere from the center of the CO_2 absorption band at 15 microns as measured by the 669 cm^{-1} channel of the satellite infrared spectrometer on board Nimbus III. Measurements were made over a 24-hour period on 8 and 9 July 1969. Radiance isopleths (heavy curves) are labeled in units of erg cm^{-2} sec^{-1} $sterad^{-1}$ $(cm^{-1})^{-1}$. The thin lines indicate the paths of the satellite over the area during the 24 hours.

The Sonic Boom

Although the sonic boom is per se probably the most important subject dealt with in this article, it is not primarily a meteorological problem. It is mainly a sociological, psychological, political, and engineering problem (*27*). We are concerned here only with the atmospheric influences on sonic boom propagation, and with the prospects for predicting the location and intensity of the boom.

The sonic boom has been called "the footprint on the ground of supersonic aircraft" (*28*); it is defined as the sound produced by the shock wave that issues from a vehicle moving through the atmosphere at sonic or supersonic speed. In Fig. 7, the typical paths of some shock waves are shown. Since wind and temperature generally vary with height, the curvature of these paths also varies, owing to refraction, with accompanying changes in the distance of lateral boom cutoff. Frequently there are "spikes" in the roughly N-shaped sonic-boom pressure signature (the trace of the deviation of pressure, with time, from the ambient pressure), as recorded, for example, by a microphone (Fig. 8). These spikes, which constitute the greatest deviation from the mean, are highly variable with respect to both space and time, and are probably due to rapid fluctuations of temperature and wind (turbulence) along the acoustic-ray path between aircraft and ground, especially within the planetary boundary layer (*29*).

Computer programs have been developed for predicting sonic boom. The program currently most favored (*30*) makes use of the simple assumption that the atmosphere is stratified—that is, that temperatures and winds vary in the vertical only; it will predict spatial averages of sonic-boom signatures, but whether it will be of acceptable accuracy remains to be seen. The small-scale variability in overpressures, documented in numerous places (*31*), suggests that the statistical theory of turbulence will provide the most useful information in this connection.

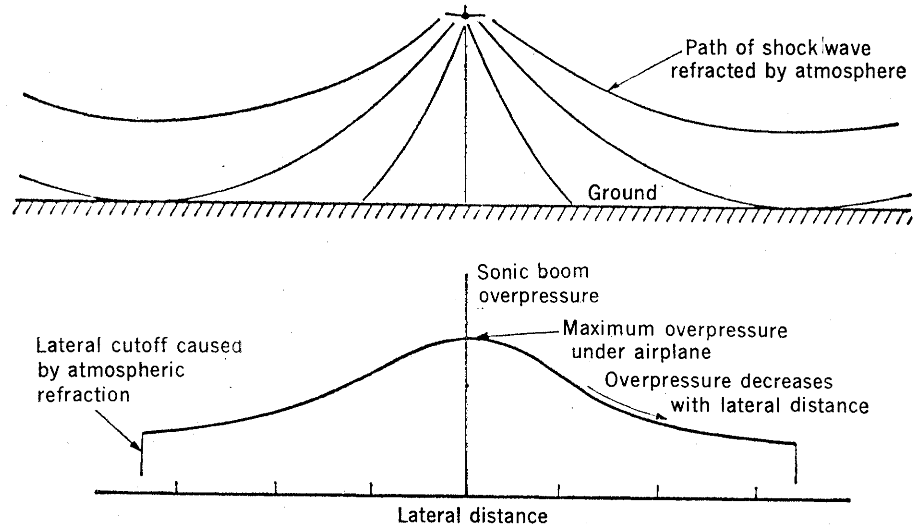

Fig. 7. Effect of atmosphere on sonic boom (see *42*). (Top) Paths of refracted acoustic rays; (bottom) surface distribution of overpressure corresponding to the refraction pattern.

Cosmic Radiation

The SST will be the first commercial aircraft to be subjected to cosmic radiation in quantities which may on occasion be biologically significant. Although this is not strictly a meteorological problem, it is sufficiently important to warrant brief discussion here. The radiation problem becomes increasingly important at the higher altitudes, where less atmosphere is available to shield the aircraft.

Galactic cosmic rays, originating far beyond our solar system, provide a more or less steady radiational background at proposed SST cruising levels, but it is not expected that the doses received from this source by passengers and crew will ever constitute a hazard. On the other hand, streams of high-energy particles (known also as solar cosmic rays and proton showers) emitted by the sun during solar flares may constitute a hazard, especially at high latitudes. The particle emissions tend to attain maximum frequency and intensity near times of sunspot maxima, which occur approximately every 11 years.

While there is some dispute concerning what should be designated a maximum permissible radiation dose, the International Commission on Radiological Protection has recommended for the general population a yearly permitted individual dose of 0.5 rem (*32*). Calculations of dose rates that may be expected during flight under anomalous radiation conditions near SST cruising levels have been made, on the basis of hypothetical flares modeled after actual events. The results indicate that, for a remarkably strong radiation event, the dose may be as great as 1 rem, or twice the maximum recommended yearly dosage, over polar areas (*33*). Considerations such as this will make it advisable for the aircraft to descend to lower altitudes during such radiation storms.

A system of short- to medium-period forecasting (10 minutes to 3 days) of solar flares is at present available, from

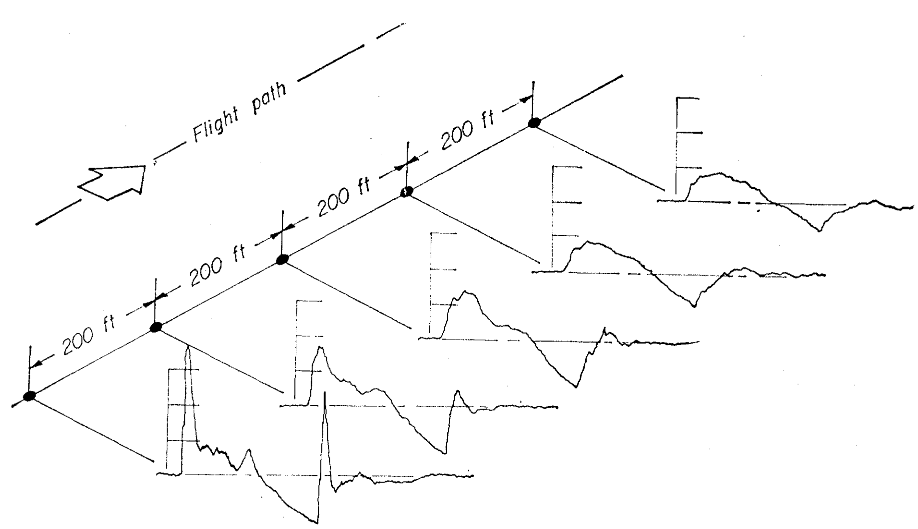

Fig. 8. Sonic-boom pressure signatures for an airplane at an altitiude of 9000 meters and with a Mach number of 1.7 (see *43*).

ground-based observations of the sun's disk and from the monitoring of high-energy particles reaching ground level (*34*). However, the phenomenon to be reported by such a system sometimes interferes with radio communications. Therefore, even if a system of urgent communication is devised, there can be no certainty that the information can be transmitted to an aircraft in flight. Since the problem is greatest at high geomagnetic latitudes, transpolar flights would be most affected.

The ground-based system of solar-flare forecasting would be of value in alerting both flight planners and crew to the fact that a radiation storm is probable or has occurred and that radiation levels may be high at cruising altitudes. At times when solar flares are probable, any high-latitude flight may require knowledge of weather conditions at altitudes lower than cruising level along the entire route, in case descent should become necessary.

In view of prospective needs for immediate in-flight information on radiation and of the problems associated with ground-based systems, instrumentation for on-board radiation monitoring appears desirable. There are plans for the Concorde to carry this instrumentation, but it is not yet known whether other supersonic aircraft will do so.

Further Considerations

Ozone, a highly toxic constituent of the atmosphere, occurs at maximum concentration at altitudes slightly above proposed SST cruising levels (*35*). It is expected, however, that the compressional heating of the air in supersonic flight will produce sufficiently high temperatures at the ventilation intake of the cabin to destroy most of this gas, and filters will be provided to eliminate any that may remain (*4*). Consequently ozone is not considered a potential hazard to passengers or crew. Moreover, while it can cause rapid deterioration of some materials, all vulnerable parts of the SST will be ozone-resistant.

Naturally occurring lithometeors, which could have an erosive effect on the skin or engines of aircraft at supersonic speeds, have been occasionally observed in significant quantities at stratospheric levels. Most noteworthy have been the stratospheric dust clouds caused by the eruptions of Krakatoa in 1883 and of Mount Agung in 1963. The clouds from the Krakatoa eruption were observed to circle the earth many times (*36*). It will be necessary to monitor any future phenomena of this nature, and to determine critical concentrations, the effects of various particle sizes, and the best means for the SST to keep exposure to a minimum.

There may also be a problem of atmospheric contamination by debris from thermonuclear explosions. Most of the radioactive particles found in the stratosphere have radii between 0.02 and 0.15 micron and require between 20 and 300 months to fall through a 5-kilometer layer at SST cruising levels (*37*). All particles remaining in the troposphere are washed out within a few weeks at most (*38*). At present, the concentration of radioactive materials in the stratosphere is much lower than it was during the period of intensive atmospheric testing of nuclear devices, in late 1961 and 1962, and it is being constantly monitored (*39*).

Much interest hs been expressed in the effects the SST might have on the stratospheric environment. Some experts believe that the injection of large amounts of H_2O, CO_2, and other contaminants might upset the natural radiation balance of the layer (for example, perhaps by partial destruction of ozone), and this in turn could affect tropospheric weather. Others think that concentrations of these substances would remain negligible. A comprehensive statement on this subject is contained in the 1966 "Final Report of the Panel on Weather and Climate Modification to the Committee on Atmospheric Sciences of the U.S. National Academy of Sciences–National Research Council" (*40*).

Summary

With the advent of the supersonic transport, information on meteorological conditions at certain levels of the stratosphere will, for the first time, be needed for routine civil-aviation operations. Research studies are rapidly increasing our knowledge of the composition and circulation of this layer, and we can reasonably prepare to add forecasts of weather conditions at the higher altitudes to the spectrum of meteorological services to aviation. In essence, the forecast system, which now covers the layer from the earth's surface to an altitude of 12 kilometers, will be extended to 20 kilometers and possibly higher altitudes.

The development of forecasting techniques in support of the SST may be facilitated by exploiting the similarities between weather conditions in the stratosphere and those now encountered in the troposphere. Clear air turbulence, one of the major problems for the subsonic jet, has been found to occur in the stratosphere. It appears that much work remains to be done to improve forecasts of this phenomenon. Thunderstorms, although hazardous in terms of supersonic flight, can be detected by several methods, the most promising being the use of geostationary satellites capable of nearly continuous monitoring.

Wind effects should be considerably smaller for the SST than for subsonic aircraft, mainly because the SST will be airborne for much shorter times, and because wind speeds at SST cruising levels are generally lower. Even so, forecasts of wind may be necessary during the winter because wind variability over certain geographical regions appears to be sufficiently high during winter months to affect the economics of operation. Knowledge of temperature fields appears to be very important—again, especially in winter, when rapid changes take place at stratospheric levels. Knowledge of ozone distribution could prove to be of value in the development and implementation of a temperature forecast system.

The possible hazards of solar cosmic radiation will be kept to a minimum through the use of a ground-based forecasting system that has been in operation for some time, and possibly also through on-board detection equipment. The problems of sonic boom intensity at ground level may be less tractable. Amplification and attenuation of the boom as a result of meteorological conditions can be roughly predicted, but it remains to be seen whether current observations are suitable for such prediction.

In recent years, great advances have been made in obtaining data on atmospheric phenomena at stratospheric levels; but still more complete coverage will be needed for SST operations. Programs such as the World Weather Watch, a cooperative program sponsored by the United Nations for expanding global observations of atmospheric phenomena, will certainly be of benefit. Another source of valuable information will be the SST itself—an SST in transatlantic flight, for instance, can provide data for immediately following flights. Finally, the satellites of the ESSA series and later-generation spacecraft, with their ability to depict continuously the three-dimensional distribution of temperature and pressure (and, therefore, of wind) over the entire globe, will undoubtedly play a major role in providing much of the required meteorological information.

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Oxidative and Photosynthetic Phosphorylation Mechanisms

The chemistry reflects a possible evolutionary pattern for the driving force of life.

Jui H. Wang

To maintain life, all living systems must feed on free energy from their surroundings either directly in the form of light or in the form of stored chemical free energy converted from light. During respiration, the free energy stored in the substrate or food is released by the controlled aerobic oxidation in mitochondria. Part of this free energy is utilized to synthesize adenosine 5′-triphosphate (ATP) (*1*) for growth and reproduction according to genetically predetermined codes and for adaptation to the environment as required by circumstantial factors.

The biosynthesis of ATP from adenosine 5′-diphosphate (ADP) and inorganic phosphate (P_i), coupled to the oxidation of substrates, is known as oxidative phosphorylation and takes place (*2, 3*) mainly in the respiratory chain embedded in the mitochondrial membrane. But by what molecular mechanism is the free energy liberated in an oxidation process utilized to drive a phosphorylation reaction in which P_i and ADP condense to form ATP and water? There is not yet a universally accepted answer.

Model Reactions

The only simple electron transfer reaction that has been reported to cause P_i to condense with adenosine 5′-monophosphate (AMP) or ADP to form ADP or ATP, respectively, is the aer-

The author is Eugene Higgins Professor of Chemistry and Molecular Biophysics, Yale University, New Haven, Connecticut 06520.