sediments and wind-borne material. The influent sulfur has an isotopic value of about 10 per mil. Sulfate in the lake shows values of about 15 per mil, and bacteriogenic sulfur averages near 5 per mil. On the basis of only the new input of 20,000 tons of sulfur, a balance calculation suggests that bacteriogenic sulfur amounts to about 10,000 tons per year. Some of this H_2S undoubtedly reacts with metallic ions to form sulfides, but Great Salt Lake shows little sulfide in the sediments, so that much of the H_2S produced there may be oxidized (*6*).

On an annual basis, 10,000 tons of sulfur amounts to about 10 percent of that released by the smelters, but the bacteriogenic production is seasonal, and thus, during periods of peak activity, the bacteriogenic sulfur may even be the dominant source in the area. It is quite clear that an improved understanding of the role of sulfate-reducing bacteria is essential to the rational management of sulfur in some environments, as suggested by earlier studies (*3*).

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Satellite Radiation Measurements and Clear Air Turbulence Probability

Abstract. *Radiance gradients determined from data gathered by the infrared spectrometers aboard the Nimbus III and Nimbus IV satellites were related to the probabilities of clear air turbulence, as inferred from regular pilot reports. Such radiance gradients represent rather large-scale vertical wind shear. Clear air turbulence is least likely in regions where the radiance gradient is small. The results of this exploratory study show that satellite data can be used to design flight paths so that the probability of encountering clear air turbulence is extremely small.*

The satellite infrared spectrometer (SIRS), carried on board the Nimbus III and Nimbus IV spacecraft, is designed to measure the vertical temperature structure of the atmosphere. The eight observing channels of the SIRS measure the amount of infrared radiation emitted vertically upward by the atmosphere in seven narrow intervals of the carbon dioxide band and in one interval in the 11.1-μm atmospheric window (*1*). The radiance received in channel 4 is a measure of weighted average temperatures, with maximum weight near 9 km (*2*), which is near the altitudes at which commercial aircraft operate while in flight.

About 45,000 pilot reports issued over the continental United States were supplied by American Airlines for the months of September 1969 and January, March, and June 1970. These were sorted to isolate the reports which coincided (within 3 hours and 1 degree of latitude and longitude) with the passage of the Nimbus III satellite. A total of 602 such coincidences were obtained.

Of interest was, not so much the value of the radiance per se, but the horizontal gradient of the radiance measured by the satellite in the vicinity of the pilot report. It can be shown that, in the absence of clouds in the field of view, the horizontal gradient of the radiance measured by channel 4 of the SIRS represents a rather large-scale vertical wind shear in the atmosphere (*3*). Thus, a high value of the horizontal radiance gradient implies a large vertical wind shear near 9 km, and clear air turbulence (CAT) is most likely in areas of large vertical wind shear (*4*). The horizontal radiance gradient in the vicinity of the pilot report is denoted by the quantity ΔR_4, which is the difference between the maximum and minimum values of the radiance measured in channel 4 within 2 degrees of the latitude of the pilot report along the satellite track. Each of the 602 pilot report–satellite coincidences was classified according to the value of ΔR_4 and the degree of turbulence reported. The data in the top half of Table 1 show that the probability of turbulence varies from about 4 percent in regions of small radiance gradient (that is, $\Delta R_4 \leqq 1.5$ erg sec^{-1} cm^{-2} sr^{-1} cm) to nearly 20 percent in regions of large gradient ($\Delta R_4 > 3$ erg sec^{-1} cm^{-2} sr^{-1} cm). It is worth noting that of the three pilot reports of moderate turbulence in the sample, two were associated with the largest value of ΔR_4 encountered. Of the 11 reports of turbulence with small ΔR_4 values, four occurred in a region where there was a large horizontal temperature gradient perpendicular to the track of the satellite, so that it could not be detected from the satellite data.

We stated that the radiance received by channel 4 of the SIRS comes from levels in the atmosphere centered near 9 km. However, some radiation is being received in channel 4 from levels well above and below 9 km. What are the effects of this extra radiation on the values of ΔR_4, and can they be removed? Since channel 5, which receives radiation from levels centered near 13 km, has small ΔR values (typically about one-quarter of the corresponding ΔR_4 values), the contribution of higher-level radiation to ΔR_4 is small. However, the radiation received from lower levels of the atmosphere does have an effect on ΔR_4. For example, if there is a large north-south temperature gradient near 6 km, we would expect the value of ΔR_4 to be fairly large, since channel 4 receives some radiation from that level. But we would not expect the aircraft to report turbulence, since they generally fly 3 km or so higher. However, since channel 3 receives radiation from levels centered near 6 km, we would expect a large value of ΔR_3. Of the 41 pilot reports associated with large ΔR_3 values and fairly large ΔR_4 values, only one was a report of turbulence. Thus, radiance data from channel 3 can be used to improve the conditional probabilities of turbulence.

It might be expected that we could achieve similar results by using more conventional data, for example, the isotherm spacing on upper-air charts. To test this hypothesis, the positions of the pilot reports were marked on 300-mb charts. (These charts contain temperature information obtained from instrumented balloons, or rawinsondes, near an altitude of 9.2 km.) The spacing of the isotherms in the vicinity of the pilot reports was measured and compared with the turbulence reports in a contingency table similar to Table 1. Although there was a good correlation between isotherm spacing and turbulence, the correlation was not as good as that obtained by using ΔR_4 values. Even over the continental United States, where there is a dense network of rawinsonde stations, better results are obtained with the ΔR_3 and ΔR_4 values than with the isotherm spacing on 300-mb charts.

In using ΔR_3 and ΔR_4 we obtain a one-dimensional measure of a two-dimensional field, since the SIRS-A, carried on board Nimbus III, scans only vertically downward and hence makes observations only along the subsatellite track. The SIRS-B, carried on board Nimbus IV, scans to each side of the subsatellite track and thus allows us to develop a two-dimensional representation of the horizontal radiance field centered near 9 km. The data obtained from the SIRS-B when it was scanning to the side of the track should have been corrected for zenith angle. Since such corrections were not available, uncorrected data were used.

Radiance data from SIRS-B and pilot reports from the North Atlantic (supplied by Trans World Airlines) for a 12-day period in September 1970 were used in this phase of the study. An example of the horizontal radiance field derived from measurements made by channel 4 of the SIRS-B is shown (Fig. 1). The radiance field was divided into areas of large ($\nabla R \geqq 1$), moderate ($\frac{1}{2} \leqq \nabla R < 1$) and small ($\nabla R < \frac{1}{2}$) horizontal radiance gradient (∇R). The units of ∇R are ergs per second per square centimeter per steradian per inverse centimeter per degree latitude. The pilot reports were then sorted according to the value of ∇R (Table 1, bottom). Although only 19 percent of the reports originated in areas where ∇R was large, 49 percent of the turbulence reports and 75 percent of the moderate-turbulence reports originated in these areas. Moderate turbulence was reported more than 12 times as frequently in areas of large radiance gradient than in areas of small and moderate radiance gradient.

So far, we have neglected the effects of clouds on the radiance gradients. High, thin clouds have little effect on the radiance (*1*). Thick clouds, however, are opaque to infrared radiation, and therefore it is likely that some of the large radiance gradients were due, at least in part, to clouds in the field of view of the SIRS. Radiance data from lower channels should be useful in correcting for the effects of clouds, and when we used channel 3 to remove the effects of low-level horizontal temperature gradients, we undoubtedly also removed some of the effects of low-level clouds in the field of view. An attempt was made to further improve on the probability table by identifying the pilot reports for which the radiance measured in channel 4 was approximately equal to the radiance measured in channel 1 (the window channel. If the radiances in channels 1 and 4 are approximately equal, the presence of high-level clouds is indicated). It was found that these included many of the reports associated with large ΔR_4 values (and turbulence). Hence, many of the large ΔR_4 values resulted from clouds in the field of view, and the turbulence in these cases was very likely associated with the clouds (for example, near jet streams). A comparison of Fig. 1 with a satellite photograph (not shown) of the cloud cover over the same area of the North Atlantic on 18 September 1970 indicates that clouds do play a role in the radiance field, but the turbulence reported on that day is much more closely related to the radiance gradients than to the clouds.

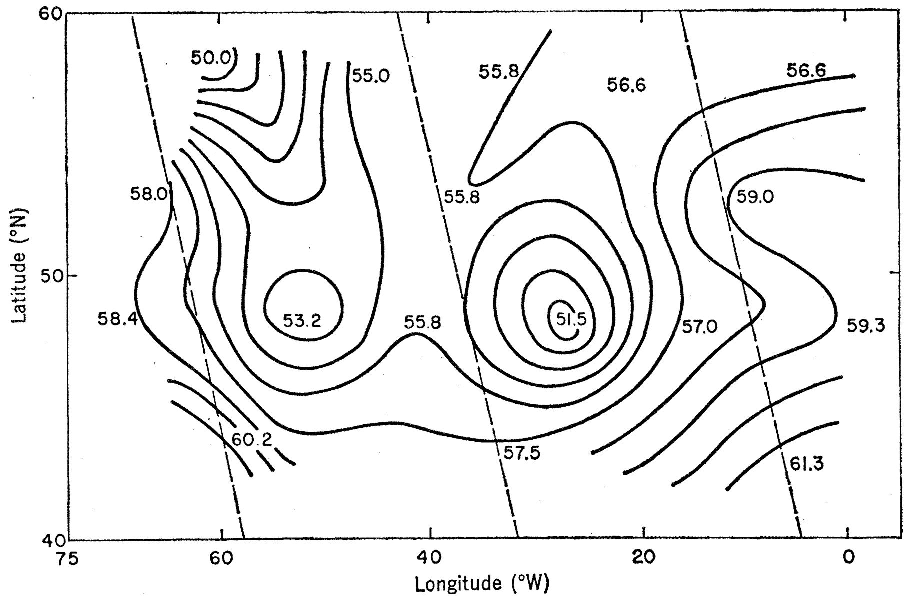

Fig. 1. Horizontal radiance field centered near 9 km altitude for 18 September 1970 over the North Atlantic. The dashed lines show the track of the Nimbus IV satellite on three successive orbits. All observations made by the satellite are made at local noon solar time. The numbers in the body of the figure are the radiances measured in channel 4. The baroclinity of the atmosphere is indicated by the isolines. Turbulence is most likely in areas of strong baroclinity (where the isolines are closest together).

Table 1. Conditional probabilities of turbulence. (*N*) Number of reports of turbulence in each category (none, light, moderate); RG, radiance gradient. The pilot reports compared with the Nimbus III (SIRS-A) data were issued over the continental United States in September 1969 and January, March, and June 1970. Those compared with the Nimbus IV (SIRS-B) data were issued over the North Atlantic in September 1970.

RG category	Turbulence (*N*)			Probability (%)
	None	Light	Mod.	
	Nimbus III			
Small	260	11	0	4.1
Mod.	166	26	0	13.5
Large	113	23	3	18.7
	Nimbus IV			
Small	1425	36	1	2.5
Mod.	1537	48	6	3.4
Large	639	66	21	12.0

This exploratory study shows that satellite measurements of radiance can be used to determine the conditional probablity of clear air turbulence and its seasonal and regional variations. Thus, satellite sounding data have a potential routine application in the design of flight paths with an extremely small probability of encountering CAT.

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3. The measured radiance is represented by the integral form of the radiative transfer equation (*1*). By taking the horizontal ascendent of this equation and combining the result with the thermal wind equation, it can be shown that the horizontal radiance gradient measured by channel 4 of the SIRS reflects the difference between two weighted mean winds, one centered near 12 km, the other centered near 6 km. Details will be included in J. A. Woods and H. A. Panofsky, in the Proceedings of the 1972 IUCRM Colloquium on Waves and Turbulence in Stratified Layers and Their Effects on EM Propagation, 6–15 June, San Diego, to be published in *Boundary Layer Meteorology*, in press.
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Mercury Content of Common Foods Determined by Neutron Activation Analysis

Abstract. *The mercury contents in samples of flour, sugar, nonfat dry milk, potatoes, hamburger, chicken breast, shrimp, liver, eggs, and whole milk were determined by neutron activation analysis. The mercury was separated by anion exchange chromatography and precipitated as the sulfide. The mercury concentrations for all these foods were below 50 parts per billion.*

Data accumulated by the U.S. Food and Drug Administration and other agencies have confirmed that fish can contribute mercury to the diet. Fish, however, represents only a small portion of the normal dietary components of the American public. Data reported by Jervis *et al.* (*1*) indicate that the occurrence in common foods of mercury at significant concentrations may be widespread. We therefore set out to determine if other foods besides fish contain significant amounts of mercury. The foods selected were those specific foods or food groups that have a high total nationwide consumption. We made exceptions to this in including liver and shrimp because these foods might be expected to be accumulators of mercury from their respective environments and therefore be useful secondary indicators of mercury. Representative nationwide samples of the following types of food were collected for analysis: flour (wheat); milk (nonfat dry and whole); sugar (cane); potatoes (white, raw, unpeeled); beef (raw, ground hamburger); chicken (raw, boned breast); shrimp (frozen, peeled, deveined); liver (beef); and eggs (shelled).

To avoid contamination, food samples were shipped in glass jars and handled in a "clean room" until they had been sealed into quartz irradiation vials. The contents of the jars were thoroughly mixed before shipment and before any sampling was done. Food samples which had a water content of more than 15 percent were freeze-dried in order to lessen any pressure increase when the sample, enclosed in a sealed quartz vial, was exposed to the neutron flux. In practice, a sample of 1 to 10 g was withdrawn with a stainless steel spatula, transferred to a 25-ml Erlenmeyer flask, frozen in liquid nitrogen, and freeze-dried in a freeze-dry apparatus (VirTis). After the sample had reached ambient temperature it was kept under vacuum for two additional hours. The freeze-dried sample was finely pulverized, transferred to a small polyethylene vial, and placed in a desiccator.

For each analysis, approximately 200 mg of a dry food sample was accurately weighed directly into a clean quartz vial, which was then sealed with an oxygen-methane torch. The mercury standard consisted of 12.5 μg of mercury (in the form of mercuric acetate in 1*M* acetic acid) which was adsorbed onto about 30 mg of powdered silicon dioxide and sealed in a quartz vial. The standards and samples were packaged and irradiated in a neutron flux of approximately 6×10^{13} neutron cm^{-2} sec^{-1} for 4 hours in the 10-Mw research reactor at the National Bureau of Standards (NBS), Gaithersburg, Maryland. In order to avoid exposing the personnel to the radiation and to allow short-lived radionuclides some time to decay, the samples and standards were processed approximately 1 week later. The quartz vials were washed with aqua regia after irradiation to remove any contamination from the outside of the quartz vials, an important cause in the early phases of this work of very high and quite variable results. The importance of avoiding contamination cannot be overemphasized for mercury measurements at the parts per billion (ppb) level.

Because the mercury content of most of these samples was quite low, a chemical separation was needed to enhance the 279-kev gamma-ray peak of ^{203}Hg with respect to the background. Mercury was separated by a procedure developed by Jervis *et al.* (*1*) involving anion exchange chromatography and sulfide precipitation. An alternative electrodeposition procedure of Sjöstrand (*2*) was found to give equivalent results at all concentrations of mercury. However, for the data reported here we used the procedure of Jervis *et al.* (*1*) because it was readily adaptable to processing a large number of samples and did not require any

Table 1. Analyses of mercury standards and of samples examined in several laboratories.

Material	Mercury (parts per million)		Reference
	This work	Other work	
NBS orchard leaves*	0.148 ± 0.010	0.155 ± 0.006 .162 ± .010	(*7*) (*8*)
International Atomic Energy Agency standard flour*	4.6 ± .5	4.87 ± .06 4.9 ± .3	(*7*) (*9*)
Food and Drug Directorate flour No. 32573	0.011 ± .003	0.011 ± .004 .007 to .02	(*7*) (*10*)
Swedish fish No. 410-30	1.29 ± .13	1.14 1.17	(*11*) (*8*)
Swedish fish No. 410-28	2.16 ± .22	2.24 2.20	(*8*) (*11*)
Bowen kale*	0.25 ± .03	0.23	(*9*)

* Standard material.