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MONITORING EL CHICHON AEROSOL DISTRIBUTION USING NOAA-7 SATELLITE AVHRR SEA SURFACE TEMPERATURE OBSERVATIONS

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RESUMEN

El velo de polvo de la erupción volcánica de El Chichón en abril de 1982 ha tenido un notable efecto sobre la capacidad del AVHRR del satélite NOAA-7 para registrar la temperatura de la superficie del mar (SST). Las pequeñas partículas de ácido sulfúrico de una micra o aún menos de tamaño en la estratosfera atenúan la radiación de la Tierra causando un desplazamiento (sesgo) negativo en los SSTs producidos operacionalmente por NOAA. Hemos utilizado este desplazamiento para observar mensualmente la evolución y dispersión de la nube de aerosol a medida que se esparcía rápidamente hacia el norte durante los meses de noviembre y diciembre de 1982 y hasta la primavera de 1983.

ABSTRACT

The dust veil from the April 1982 volcanic eruption of El Chichón has had a marked effect on the ability of the NOAA-7 satellite's AVHRR to monitor sea surface temperature (SST). Small micron and sub-micron sized particles of sulfuric acid in the stratosphere attenuate the radiation from Earth causing a negative offset (bias) in NOAA's operationally produced SSTs. We have used this offset to monitor the evolution and dispersion of the aerosol cloud on a monthly basis as it spread rapidly northward during November and December 1982, and into spring of 1983.

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INTRODUCTION

Satellite measurements from NOAA-7 AVHRR data have been scrutinized to examine the impact of the eruption in early April 1982 of El Chichón on the satellite data. It was known in May 1982, one month after the eruption, that an overall increase in albedo had occurred (Strong *et al.*, 1982). A marked decrease in the number if daytime satellite retrievals of sea surface temperatures (SST) was the most obvious consequence. These retrieval reductions occurred in the 15N to 25N latitude band affected by El Chichón (Robock and Matson, 1983). By June 1982 it was evident that many of our Earth observations from NOAA-7 were going to be affected by the developing aerosol cloud from the Mexican volcano. The importance of not only monitoring the aerosol cloud, but also addressing the effects it might cause on the climate system, is being stressed by the climate modelling community. We are attempting to respond to these pleas, by supplying credible data of SST and Earth radiation budget corrected for biases El Chichón has imposed. It is not a trivial task but progress is being made.

GROWTH OF THE EL CHICHON CLOUD

In November of 1981, NOAA/NESDIS began deriving sea surface temperature from NOAA-7 satellite AVHRR data using multispectral algorithms (MCSST - McClain *et al.*, 1983). After the eruption of the El Chichón volcano, the number of daytime retrievals of MCSST was drastically reduced due to cloud tests intended to eliminate cloudy scenes. In addition, pronounced negative biases (temperature lower than those from ships and buoys) were present in the nighttime observations that passed the tropospheric cloud screening tests (McClain, *et al.*, 1983). Drifting buoy validation statistics of matchup verification had been showing 0.5°C accuracies (RMSD) before the eruption and continue to show similar accuracies outside the region over which the cloud has spread (Strong and McClain, 1984). Validations of MCSST with large moored buoys under the aerosol "cloud", although not quite as accurate (1.1°C RMSDs) have been more substantially affected by these negative offsets, especially those several buoys in the Gulf of Mexico and one off Hawaii; see Figure 1. The final and most awesome eruption of 4 April marks the start of a −1.5°C bias over the Gulf of Mexico buoy location. Although matchup offsets during the first month or two barely exceeded −2°C, "cloud filtering" techniques used in the SST extraction procedure undoubtedly eliminated many of the more substantial offsets. That bias remained fairly constant until 25 June, when apparently an increased level of aerosol moved north over the buoy location, causing offsets in derived MCSST exceeding −2°C. Although these offsets had diminished somewhat by autumn, other buoys at higher latitudes off both coasts were showing −1 to −2°C biases of satellite MCSST. These errors continued throughout the winter and only this spring (1983) have begun to decrease.

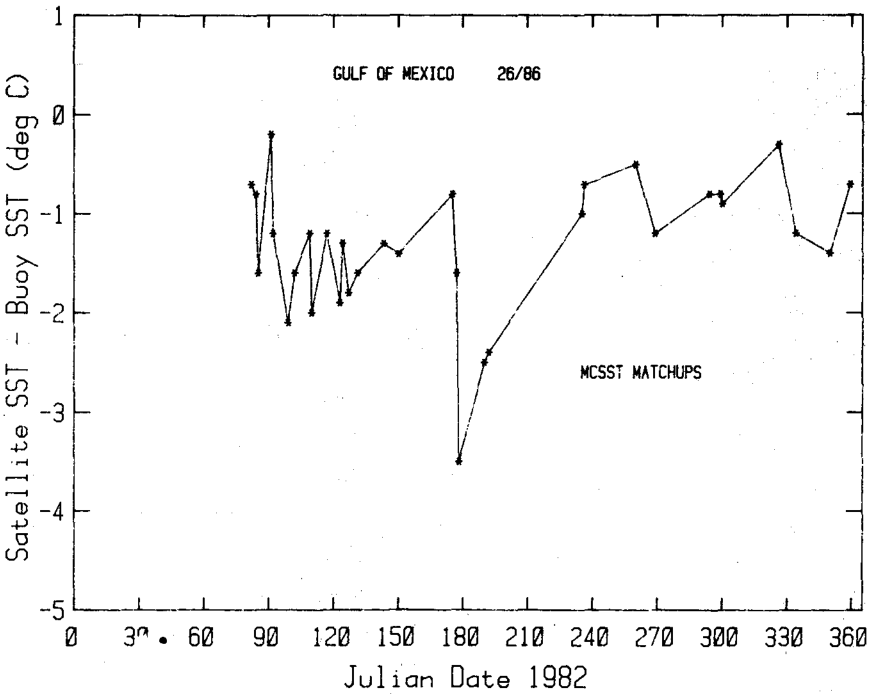


Fig. 1. Difference (bias) of satellite MCSST and NOAA fixed buoy (#42003) SST during 1982. Note: El Chichón eruption (last) on Julian Day 94.

The negative offset observed is caused by absorption due to sulfuric acid aerosol particles formed from gases in the original volcanic cloud (NASA, 1982). Generally, the greater the aerosol concentration the greater the negative offset. Thus, it has been possible to monitor the evolution of the stratospheric aerosol cloud by tracking, on a monthly basis, the observed negative biases in the MCSST product. Monthly distribution charts, Figures 2 (a through k) were constructed by substracting the *ship only* SST analysis (NWS) for each month from the *satellite only* SST analysis made by NESDIS, using all daytime and nighttime MCSST retrievals.

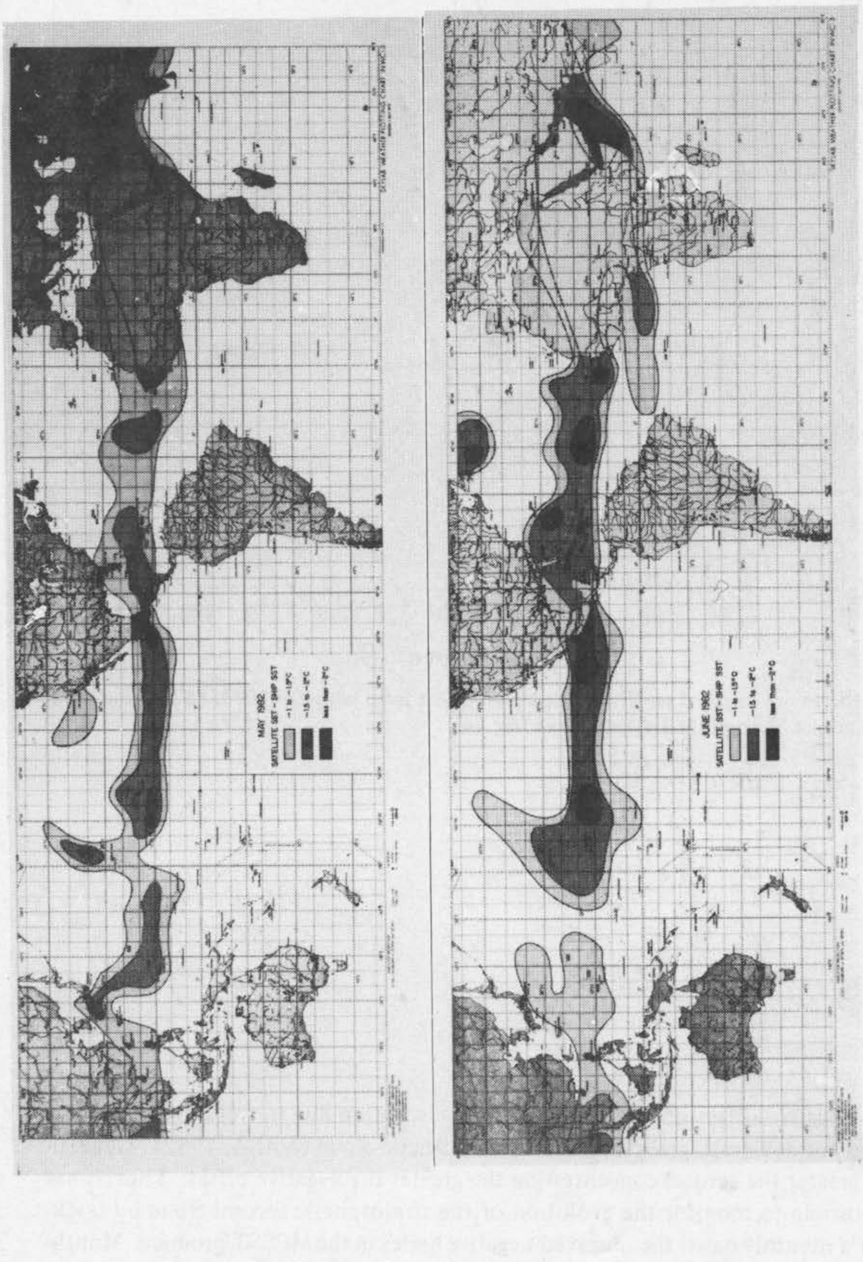
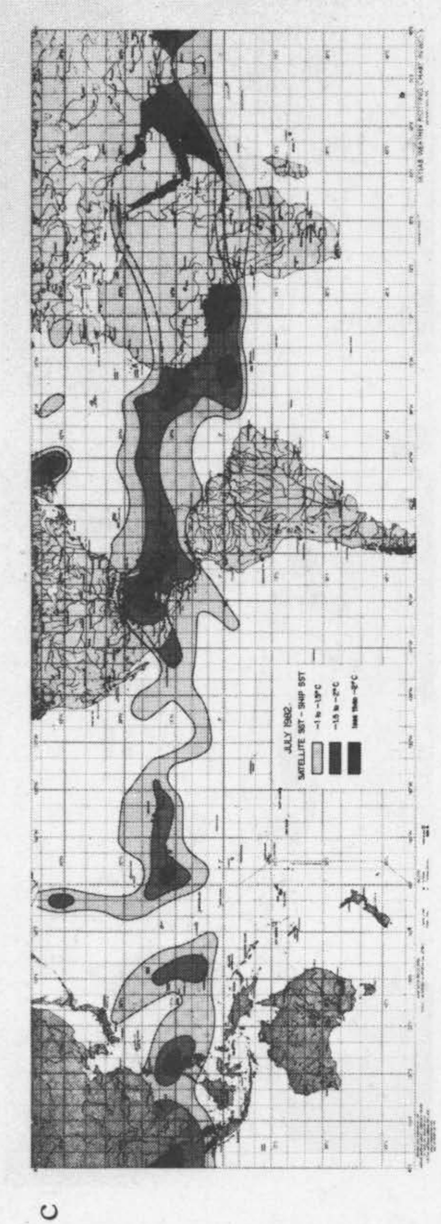
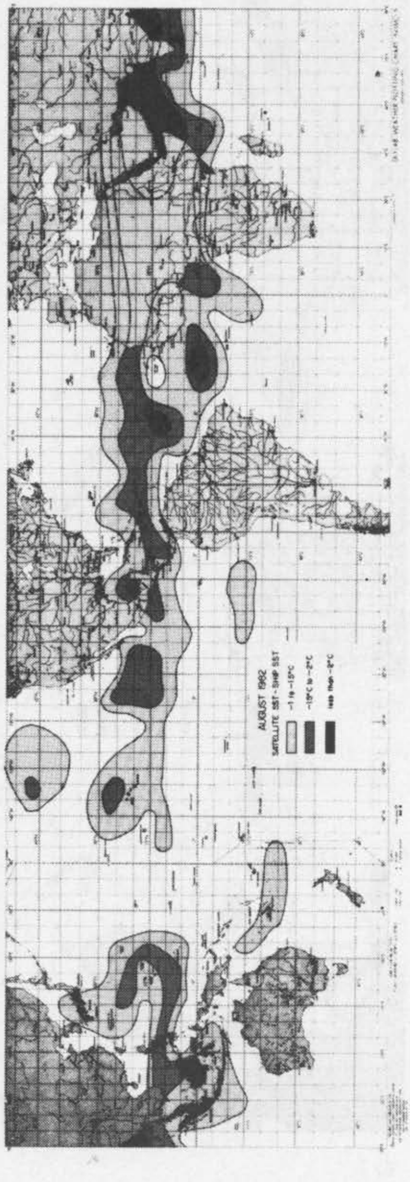


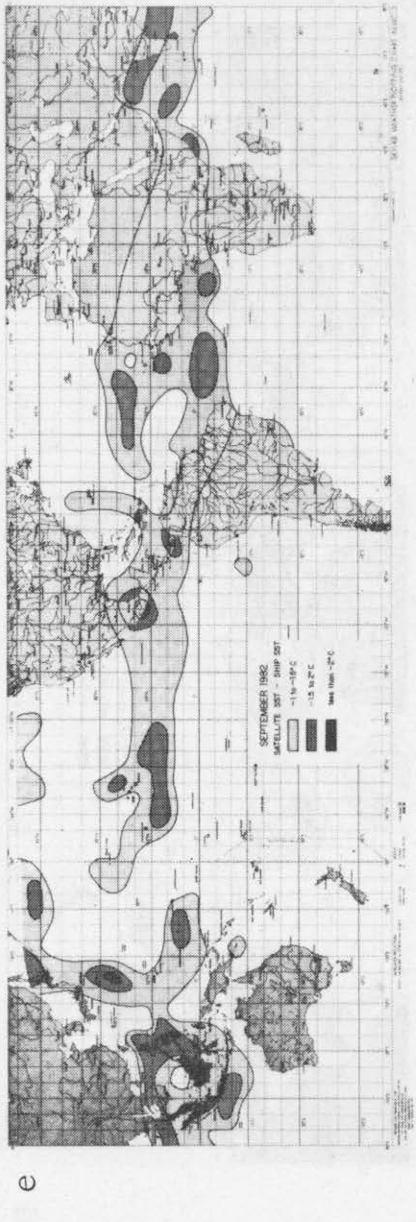
Fig. 2a-k. Global distribution of negative SST bias from monthly mean data for May (a), June (b), July (c), August (d), September (e), October (f), November (g), December (h) 1982 and January (i), February (j), March (k) 1983.


JULY 1982
SATELLITE SST - SHIP SST
-1 to -1.5°C
-1.5 to -2°C
less than -2°C

c


AUGUST 1982
SATELLITE SST - SHIP SST
-1 to -1.5°C
-1.5°C to -2°C
less than -2°C

d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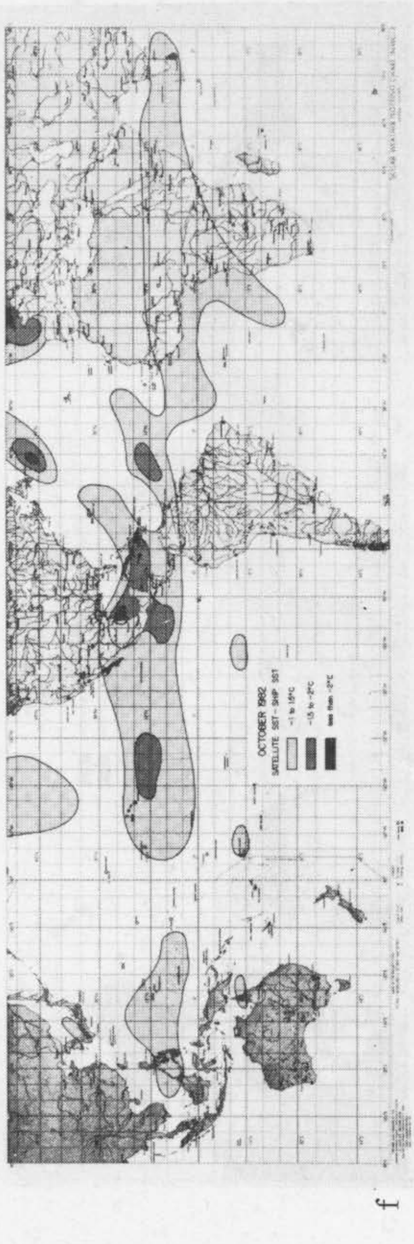
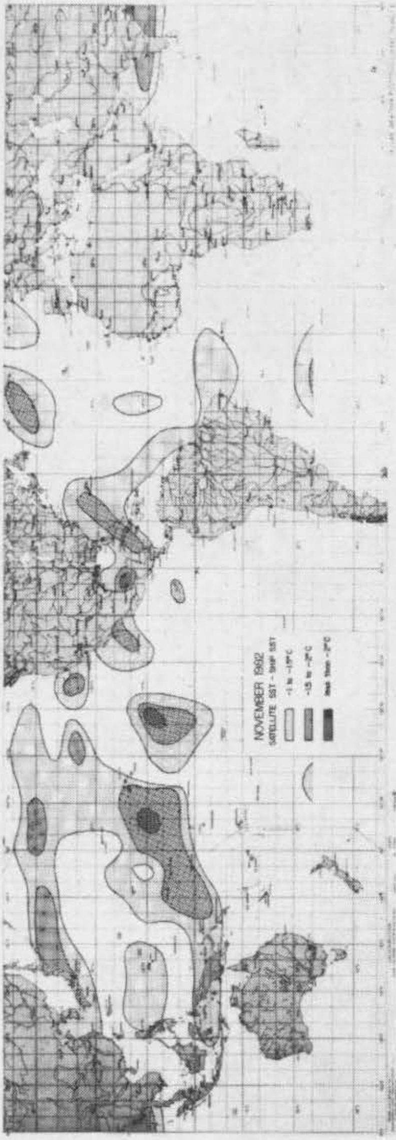
SATELLITE SST - SHIP SST
less than -2°C

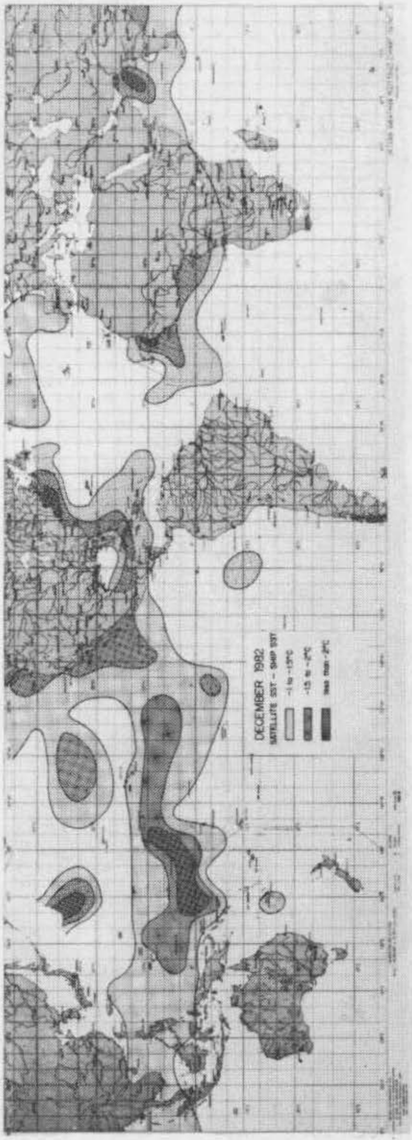
e


OCTOBER 1982
SATELLITE SST - SHIP SST
less than -2°C

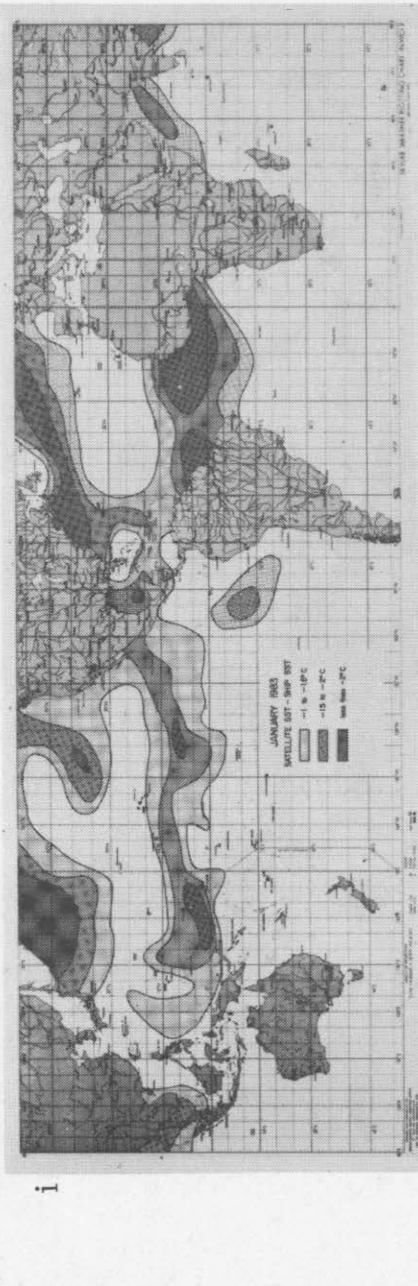
f


NOVEMBER 1982
SATELLITE SST - SHIP SST

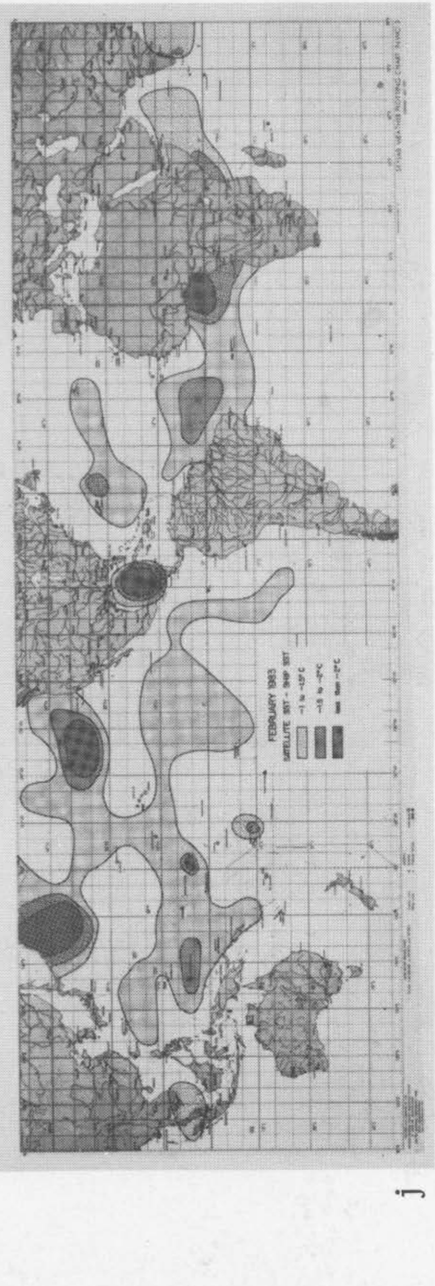
g


DECEMBER 1982
SATELLITE SST - SHIP SST

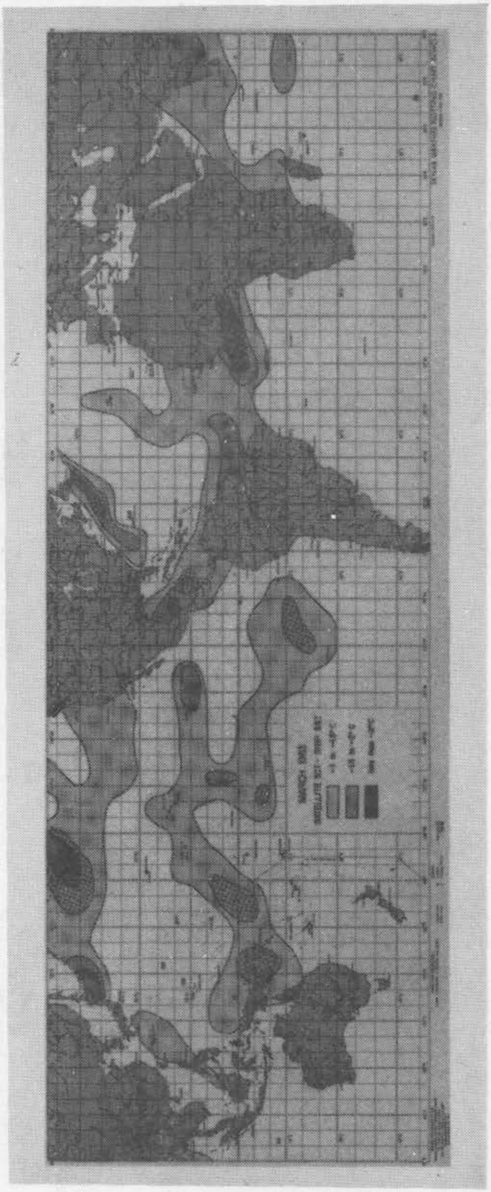
h


JANUARY 1983
SATELLITE SST - SHIP SST

i


FEBRUARY 1983
SATELLITE SST - SHIP SST

j



K

Latitudinal profiles of zonal averages of these monthly differences have been constructed over the past year to monitor dispersion of the volcanic aerosol. In the time plot shown in Figure 3, we have weighted each latitudinal average by the decreasing proportionate area it represents from equator to pole. This makes biases at higher latitude have smaller weights. Furthermore, since our measurements can only be obtained over water, we have assumed the aerosol biases represented the

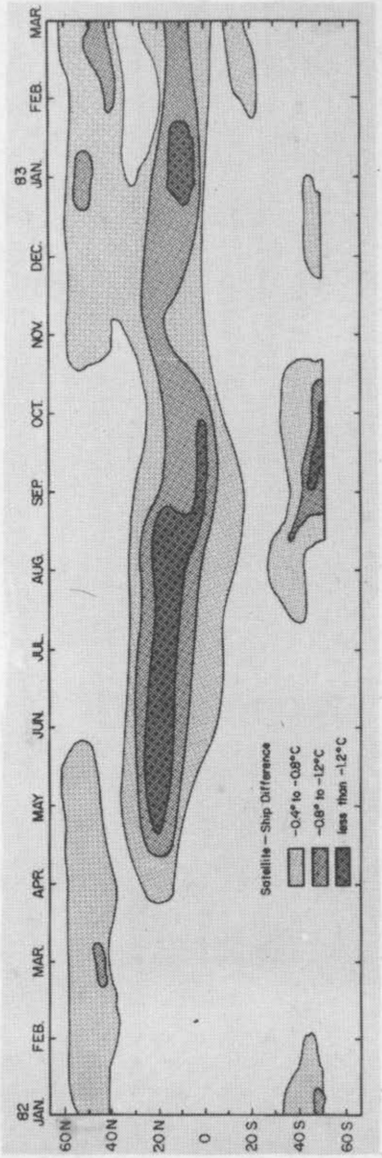


Fig. 3. Time series of monthly mean latitudinal distributions of negative SST bias from January 1982 through March 1983.

bias for the entire latitudinal band (this may or may not be correct). The temporal latitudinal plot shows results beginning with the first MCSST data in November 1981, although rigorous ship-only analyses were not only available until May 1982. The effect of the April eruption is obvious in Figure 3.

Figure 4 integrates all the monthly mean data in Figure 3 into composite weighted temporal plots of monthly mean aerosol biases over Northern and Southern Hemispheres separately and also into a final global mean.

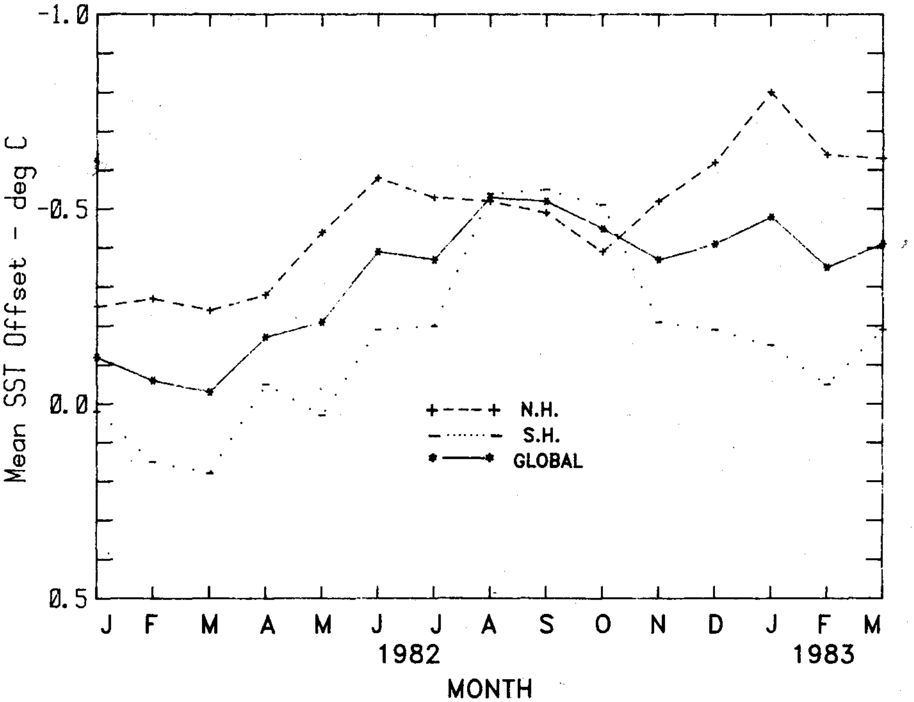


Fig. 4. Hemispheric and global summaries of Figure 3.

RESULTS AND CONCLUSIONS

From the satellite-ship SST difference charts (Figures 2a-k) a number of observations can be made about the month-to-month evolution of the El Chichón aerosol. It is probably more instructive to compare Figures 3 and 4 to these plots for a better appreciation of the month-to-month relationships over the globe.

a. Although the El Chichón "cloud" is constrained to the 0-30°N latitudinal band for several months after the eruption, with July and August 1982 showing the most severe effects, the global concentrations over the Northern Hemisphere appear to have peaked somewhat later in the year (viz. December).

b. Some transport of aerosol north of 30N was witnessed on a monthly basis before Fall, but the bulk of the aerosol continued to girdle the Earth within the 0 to 30N latitudinal belt. Heaviest concentrations tended to drift gradually toward the Equator into late summer until stratospheric breakdown began in October.

c. An intense appearance of material was indicated from the AVHRR bias data in the Southern Hemisphere between August and October that is not understood at this time, as is the bias that appears during November 1981 in Figure 3. The former bias also is evident in Solar Mesospheric Explorer (SME) data (Thomas, 1982).

d. The "Mystery cloud" may be apparent north of 40°N between January and May 1982. This feature has been referred to by many authors and its source is still unknown (*AGU*, 1982).

e. Overall aerosol bias levels increased somewhat, particularly in the Northern Hemisphere during November and December, as the stratospheric circulations carried material poleward. These concentrations gave most of the United States, Europe, and Asia brilliant violet and brick-red sunsets as adequately illustrated on the August 21, cover of *Science News* (Simon, 1982).

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BIBLIOGRAPHY

American Geophysical Union, 1982, *EOS, 63,* p.499.

McCLAIN, E. P., W. G. PICHEL, C. C. WALTON and A. E. STRONG, 1983. Ocean Surface Temperatures from Space - A Multispectral Approach, submitted for publication.

McCLAIN, E. P., W. G. PICHEL, C. C. WALTON, Z. AHMAD, and J. SUTTON, 1983. Multi-channel improvements to Satellite-derived Global Sea Surface Temperatures, *Adv. Space Res., 2*(6), 43-47.

NASA, 1982. Radiative Effects of the El Chichón Volcanic Eruption: Preliminary Results Concerning Remote Sensing, Ed. W. R. Bandeen and R. S. Fraser, Goddard Space Flight Center, Tech. Memo. 84959.

ROBOCK, A. and M. MATSON, 1983. The Circumglobal Transport of the El Chichón Volcanic Dust Cloud, *Science, 221,* 195-197.

STRONG, A. E., A. GRUBER, and M. VARNADORE, 1982. An Assessment of the Impact of El Chichón on Planetary Radiation Budget and Satellite-derived Sea Surface Temperature, in *Proc. of 7th Annual Climate Diagnostics Workshop,* Boulder, CO (18-22 October 1982), NOAA, Dept. of Commerce, Washington, D. C., 371-382.

STRONG, A. E. and E. P. McCLAIN, 1984. Improved Surface Temperatures from Space - Comparison with Drifting Buoys, *Bull. Amer. Meteorol. Soc.,* 65, 138-142.

SIMON, C., 1982. Red Sky at Night (with color cover), *Science News, 122,* 8 (21 August 1982), 113-128.

THOMAS, G., 1982. Personal Communication.

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13