Tropical Moisture Response Derived from Satellite Observations Corresponding to Sea Surface Temperature Anomaly

Hyo-Sang Chung

Satellite Division, Korea Meteorological Administration Seoul, Korea

(Manuscript received 23 October 1993)

해수면온도의 ANOMALY에 상응하는 위성관측자료로부터 도출한 열대수증기 RESPONSE

정효상

기상청 위성담당

(1993년 10월 23일 접수)

요 약

해수면 온도의 positive anomaly가 주로 나타나는 구역은 대기중 습기 유입이 많은 구역뿐만 아니라 아열대 지역의 하강 운동이 일어나는 구역의 부근에서도 나타난다. 대기중 수증기의 유입은 SST anomaly에 따라 많아지기 때문에 해수면 온도의 증가는 대기를 불안정하게 하며 습윤 공기의 발달을 촉진하는 습윤 단열한 불안정상태를 초래한다. 태평양상에서 4.0 K의 SST 변화는 동태평양과 중앙태평양상에서 TOVS 수증기 채널들에 의해 관측된 휘도 온도의 10.0 K 만큼의 양의 차이를 보였으며, 적도를 따라 남태평양상의 남동쪽과 남쪽으로는 휘도 온도가 7.5 K 만큼 음의 차이를 보였다. 엘니뇨와 비엘리뇨 기간을 비교하면 중대류권 고도에서 수증기 분포를 나타내는 TOVS 적외선 채널 11(7.3μm)과 12(6.7μm)의 휘도 온도 차이는 태평양상에서 습윤 공기와 관련한 전대류권 순환과 역학 과정에서 현저한 차이가 있었음을 알 수 있다.

Abstract

The major positive sea surface temperature (SST) anomalies not only occur in the region with the most moisture increase, but also in the flank of the area with sinking motion in the Subtropics. As the large amount of water vapor has been increased by the SST anomaly, the increase of the SST is expected to destabilize the air and leads under moist adiabatic unstable conditions, to an enhanced development of moisture cluster. The 4.0 K change of SST causes the positive difference of Brightness Temperature (TB) of about 10.0k for water vapor channels of TOVS over the north eastern and central tropical Pacific Ocean, but the negative difference of TB of about 7.5 K is shifted southward and southeastward to Southern Pacific Ocean along the equator correspondingly. The difference of the TBs for IR water vapor channel 11 (7.3μm) and 12 (6.7μm) of TOVS indicative of the moisture distribution during two time periods (January 1983 and 1984), leads us to infer significant changes in the entire tropospheric circulations and the dynamic processes over the Pacific Ocean.

1. Introduction

Over the tropical Pacific Ocean, the southern oscillation is associated with considerable fluctuations in the rainfall, the SST, and the intensity of the trade winds and it has recently been correlated with droughts over India, with severe weather over North America, and with fluctuations of the averaged temperature of the northern hemispheric atmosphere (Prabhakara et al. 1985; Ramussen and Carpenter 1982). El Nino is unique to the Pacific Ocean SST on the atmospheric circulation (Cane 1983; Ramussen and Wallace 1983; Philander 1983). Throughout this event, surface wind changes cause changes of SST in the manner described by Wagner (1987) and WMO (1985). These SST anomalies feed back on the atmosphere, including further wind changes, until the entire El Nino/Southern Oscillation (ENSO) cycle is played out. Exceptionally warm surface waters due to SST anomaly result in an unusually large release of water vapor to the atmosphere which will be heated. Horizontal temperature gradients in the tropical atmosphere are small so that heating of the lower atmosphere causes rising motion. The rising motion causes the air in the surface layers to converge on the heated region. The role that the anomalies play in producing significant deviations from the climatic envelope is a subject of considerable anticipation from a view of tropical general circulation (Harrison and Schopf 1984).

Bjerkness (1966) pointed out, in a synoptic study, that the El Nino anomaly appears not only to influence the tropical belt, but also leads to changes in the mid-latitude climate through the intensification of the Hadley circulation. Rowntree (1972) studied the deviations in tropical SST and surface wind fields associated with the ENSO. He showed that anomalous precipitation related to variations of the zonal wind component near the equator and the local meridional circulation anomaly, rather than describing them in terms of the southward shift of the Inter Tropical Convergence Zone (ITCZ) and the northeastward shift of the Southern Pacific Convergence Zone (SPCZ), which are the critical kinematic features associated with the central Pacific precipitation anomaly pattern. Webster (1981, 1982) has calculated the total diabatic heating and the dynamic response of the system. He showed the results of the simple liner numerical model which sought the steady-state response of the zonally symmetric basic state of the atmosphere, as the influence of local thermal anomalies in the Summer Hemisphere (or the near-equatorial Subtropics of the Winter Hemisphere) is moderately large because the advective terms are of less importance with the smaller basic zonal winds.

In Tropics the moisture field is one that has generally received little attention. The relative humidity analyses have been dominated by the information coming from the first guess in the numerical weather prediction model rather than from the observations up-to-date. There are somewhat significant variations in monthly mean analyzed relative humidity exceed 40%, so it appears that the moisture fields are poorly known to a satisfactory degree for almost any purpose. These problems therefore impact directly on attempts to assess the atmospheric energetics and hydrological cycle. The distribution of moisture in the atmosphere (here moisture is inferred to the vapor-phase only) is of major meteorological significance. Rodger et al. (1976) concluded that the water vapor imagery may be used as a tracer to delineate tropospheric dynamics, including mid-tropospheric motions.

This study is only to show on some moisture features fundamental to an understanding of the local response of water vapor field to the process of SST variation used by the water vapor channels of TOVS. The significant variations of atmospheric moisture features can be described between two periods, but the evidence of the occurrence of tropical plumes associated with synotic scale atmospheric dynamics described by McGuirk et al. (1987)

can be provided.

2. Data Process and Analysis

The principal sources of data for this study are the SST from National Meteorological Center (NMC) and TOVS TB from National Center for Atmospheric Research (NCAR). The domain of interest region is the most frequently data sparse area in the tropical Pacific Ocean between 100°W and 150°E and 30°S and 30°N. The horizontal resoution of the SST and water vapor fields extracted by TOVS channel 11, 12 and 19 (near IR window channe ℓ; 3.7μm) is the 2.0° × 2.0° of grid space. Because of the size of the tropical Pacific Ocean, the complexity of the precipitation, cloudiness, and the paucity of the routine observations, it is necessary to turn to satellite observations to describe those fields in this region. The blended SST and anomaly data used in this study are obtained from NMC archives of surface marine observations which consist of all ship and buoy observations and multichannel sea surface temperatures, using the Advanced Very High Resolution Radiometer (AVHRR) on the NOAA polar orbiting satellite (Reynold 1983, 1988).

The moisture field based on the radiation reaching the satellite from water vapor does not come from a single surface or level, but also from some layer of finite depth. The TBs measured by 6.7μm and 7.3μm channel of TOVS are emitted by moisture content at the middle and upper layers (Shen and Smith 1971; Hillger 1984), but the TBs measured by 3.7μm channel are not representative well to the moisture.

3. Results and Discussion

The westward trade winds that prevail over most of the tropical Pacific Ocean converge on the North-Australian, Indonesian Low Pressure Zone where the air rises and where there is considerable cloudiness and rainfall. The air returns eastward at greater altitudes and sinks over the cold, dry Southeast Pacific High Pressure Zone. Furthermore, its salient feature is the ITCZ where the South-East and North-East trades meet. This narrow zonal band of rising air, cloudiness and high rainfall migrates seasonally between 3°N approximately in Winter. In the region of the weakened winds the SSTs increase as a result of complex atmospheric-oceanographic responses. The pool of anomalously warm water therefore expands and has a larger effect on the atmosphere than before, and in this fashion the oceanic and atmospheric anomalies grow in amplitude. To the east of the original anomaly two factors determine the sea surface temperatures. One is the local intensification of the trades, which increases equatorial upwelling and hence reduces the SST. The other is the weakenling of the winds west of the anomaly, which excites Kelvin waves (Harrison and Schopf 1984) that increase the SST east of the anomaly.

In Fig. la, the equatorial 850 hPa winds are the largest amplitude between El Nino year (January 1983) and non-El Nino year (January 1984) over the central and eastern Pacific Ocean. A major warming does not only occur in the region with the large precipitation increase, but also in the area with sinking motion in the Subtropics. The wind at 850 hPa decreases and becomes more westerly in the regions with the largest precipitation increase. Also in these areas the wind converges in the lower layers, while it diverges at 200 hPa (Fig. 1b). In Fig. 1b two High & Low stream function cells are straddled over the central and eastern Pacific-North American region, which show the phenomenon of Pacific-North American (H-L-H-L pattern) wave structure (Shukla and Wallace 1983).

In Fig. 2 there are two strong positive SST anomalies along the equatorial eastern and western Pacific Ocean with greater than 3.0 K in El Nino year, but moderate positive anomalies less than 3.0 K and northward

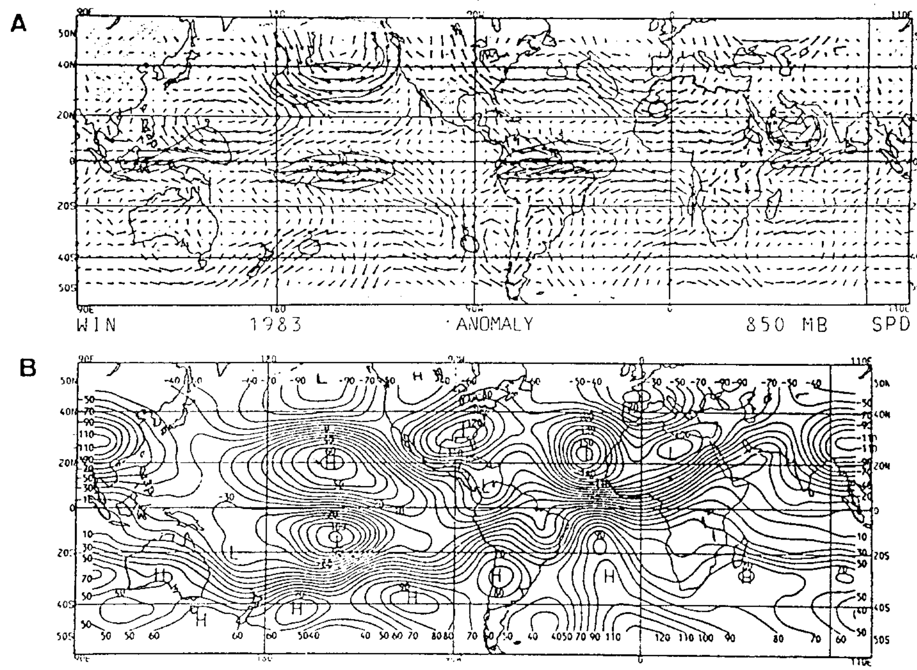

Fig. 1. a) : Wind anomaly at 850 hPa for Winter (Dec-Feb) 1982-83 and b) : 200 hPa stream function ($10^{6}m^{2}/s$) anomaly for January 1983 during the peak of ENSO (after WMO 1985).

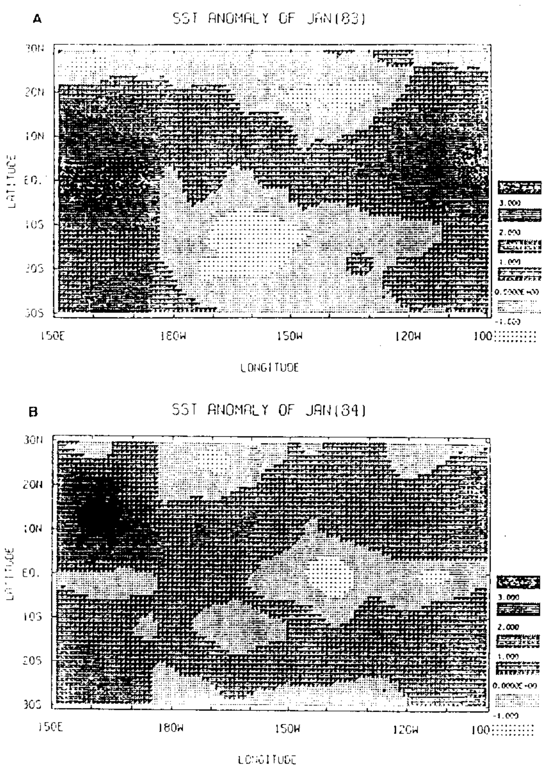

Fig. 2. SST anomaly for a) : January 1983 and b) : January 1984.

shifted in non-El Nino year. The largest positive SST anomalies occur in the eastern Pacific Ocean and the flow patterns in the lower and upper troposphere are accordingly modified. There is the significant equatorial anomaly over Latin America at this period of heavy rainfall. In the El Nino event 'year, significant perturbations in a diverse set of geographical fields occurred. The most important thing is the effective cloudiness; especially, perturbations from the climatological mean of cloud cover, height, thickness, water vapor content, drop/crystal size distribution, and emissivity. Changes in one or more of these parameters, regionally or globally, will cause corresponding anomalies in the broad-band outgoing longwave radiation (OLR) at the top of the atmosphere.

Figure 3 and 4 represent the spatial and temporal frequencies of moisture content contrasts during two periods, which show the similar patterns and cosistency well to the OLR phase and moisture convergence. These figures represent the monthly mean moisture fields of TB's of TOVS channel 11 (7.3μm) and

12(6.7μm). Most of central Pacific Ocean is covered by the warmest TB field widely in the West-East direction which implies the drier region on the middle and/or upper atmosphere, but along the equator the ITCZ is well organized, strongly active. The colder region is formed over the eastern Pacific Ocean indicative of the wet on the middle and upper level of the atmosphere. Along the equator, the ITCZ is almost separated at about 160°W but the warmer region is shifted southward reversely. This indicates that in the El Nino year the ITCZ is strongly active along the equator rather than that in the non-El Nino yeat. Significant subsidence exists, associated with the subtropical High over the central and eastern Pacific Ocean at 10°N-15°N. In the non-El Nino year, there is an apparent pattern of ITCZ which is separated and shifted the

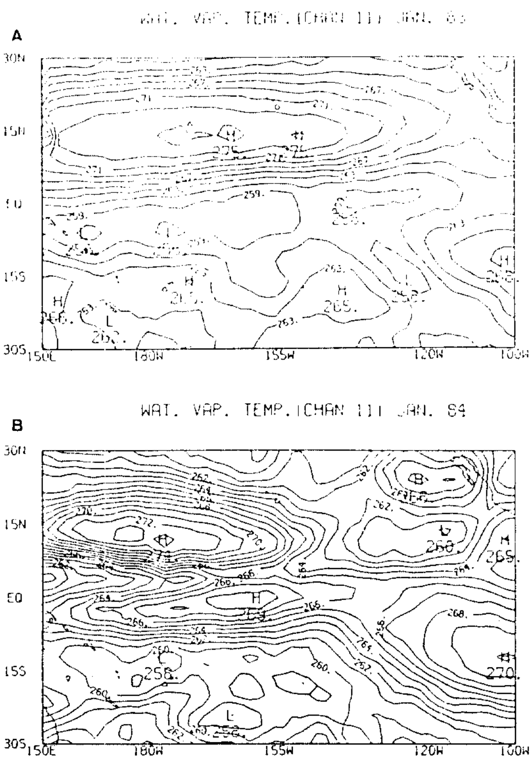

Fig. 3. The map of the TB field of TOVS channel 11(7.3μm) for a) : January 1983 and b) : January 1984.

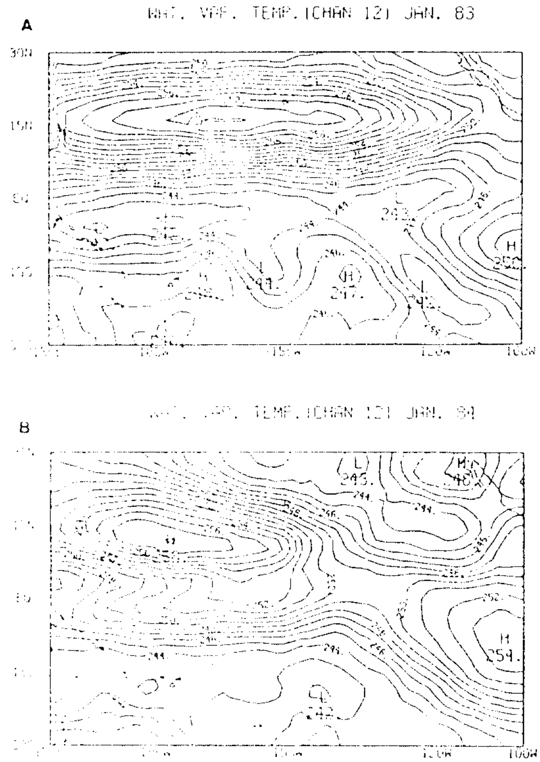

Fig. 4. The map of the TB field of TOVS channel 12(6.7μm) for a) : January 1983 and b) : January 1984.

location for the similar shape and feature. In these figures the wettest regions are shifted slightly southward. In the El Nino year the driest region occurs close to 15°N, but the half occurrences of this region indicative of wetter regions occur in the non-El Nino year. The dry regions occur frequently close to south Pacific Ocean opposedly in the non-El Nino year derived by the water vapor channel of TOVS.

Fig. 5 demonstrates the monthly mean OLR distributions at the top of the atmos-phere. In the El Nino year the ITCZ appeared to be a continuous well defined line around the equatorial zone with a strong convective zone in the central Pacific east of the date line. But in the non-El Nino year, there is a well developed wet area over East of date line and the wet zone has spread into southern Australia with the redevelopment of SPCZ.

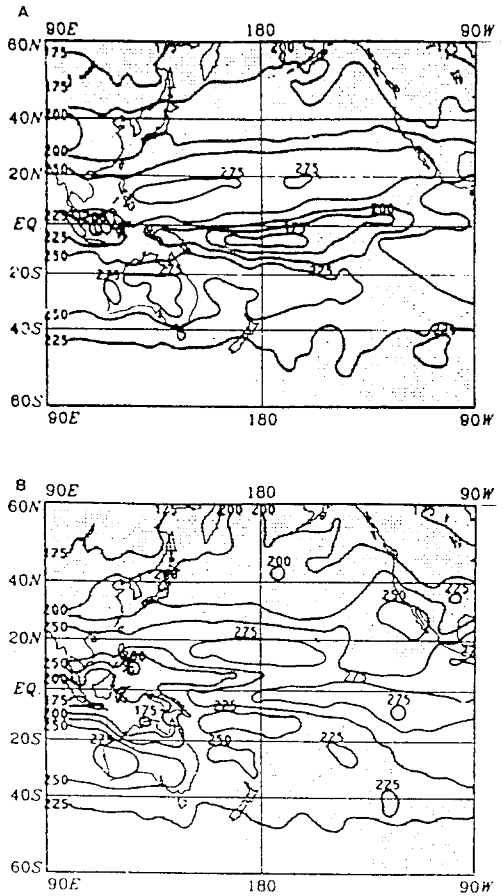

Fig. 5. Outgoing Longwave Radiation (OLR; W/㎡) at the top of the atmosphere by polar orbiting satellite for a) : January 1983, b) : January 1984 (after Arnold et al. 1987).

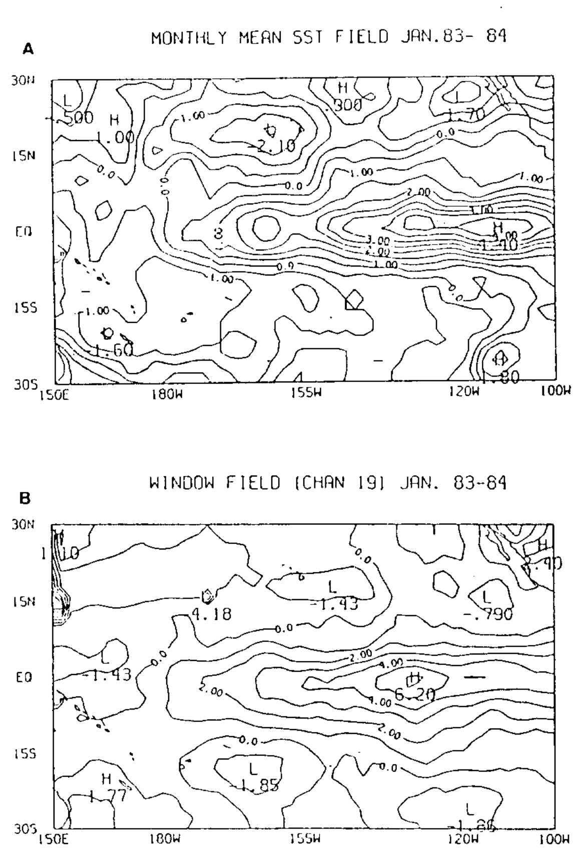

Fig. 6. The difference of SST and b) : TB field of TOVS channel 19(3.7μm) for January between 1983~1984.

Figure 6a shows the difference of the SST with the maximum value of 4.0 K over eastern Pacific Ocean along the equator, but Fig. 6b delineates that the difference of brightness temperature of TOVS channel 19(near IR window) with the maximum value of 6.0 K. The minimum value of -1.5 K over the central Pacific Ocean implies the wetter zone in the El Nino year along the equator reversely.

Figure 7a and 7b represent the difference TB for channel 11 ahd 12(Water vapor channels) of TOVS for two time periods occurred not only the significant monthly means signal of moisture fields over the warm SST anomaly corresponding to the OLR anomalies. The slight shift northward and/or westward of the location of positive difference, which indicates the drieness of middle and upper level in the troposphere, implies that the dynamical processes take place in the atmosphere described by McGuirk et al. (1987). The change of positive 4.0 K for SST corresponds to the changes of positive 10.0 K for channel 11 and 12 from 140°W eastward to 100°W, but the change of negative 7.5 K is indicative of a well-organized active ITCZ along the equator.

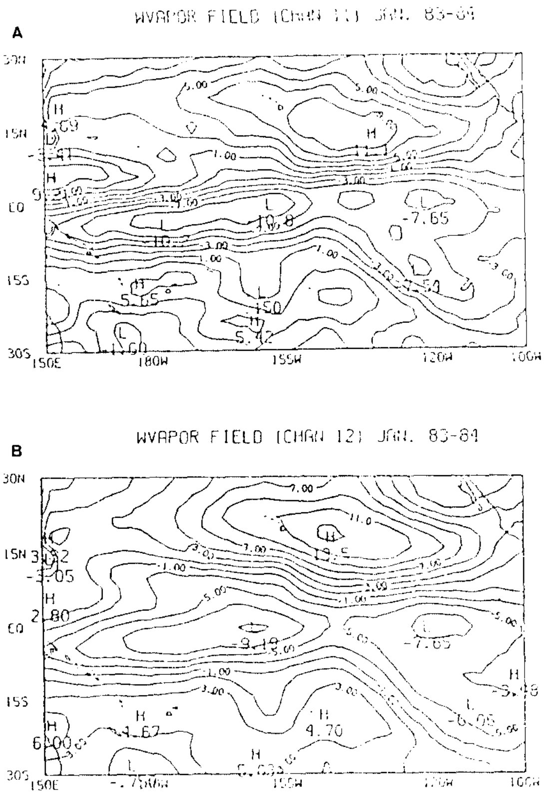

Fig. 7. The difference of TB field of TOVS channel 11 (7. 3μm) and b) : TB field of TOVS channel 12 (6. 7μm) for January between 1983~1984.

4. Conclusion

The spatial and temporal moisture distribution derived from TOVS channel 11 and 12 over the Pacific Ocean are consistent with to the logitudinal distribution of the characteristics of moisture burst. The difference of the TBs for IR channel 19 and water vapor channel 11 and 12 of TOVS indicative of the moisture distribution during two time periods, leads us to infer significant changes in the entire tropospheric circulations and the dynamic processes over the Pacific Ocean. The intense drieness is accompanied by well-organized subusidence to the northern and western Pacific Ocean, but the convective activity is accompanied to the south-eastern Pacific Ocean along the equator.

The change of SST of 4. 0 K causes the increase of TB about 10. 0 K for water vapor channels at the location of central and eastern Pacific Ocean implied the driness of middle and upper layer in the flank of the warming region over the northeastern Pacific Ocean, but the decrease of TB about 7. 5 K, which represent the active ITCZ, shifted southward to Southern America and along the equator. The northward and westward shift of the positive TB's, reflecting the drieness are consistent with the upper subsidence and may be due to the changes in the moisture field, one has to drive the accurately horizontal precipitable water distributions which will be retrieved by using the algorithms of the combinations of the several TOVS channel's TBs in the near future.

Acknowledgements. Thanks are especially to Dr. J. McGuirk in Texas A&M University for the opportunity to participate in the Tropical Pacific Moisture Variability project, and for sharing his satellite experiences and much valued assistance. I wish to empahsize my special gratitude to Dr. R. W. Reynold in climate Analysis Center of NMC to provide the global sea surface temperature data.

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