

Paper No. 54

REMOTE SENSING OF SEASONAL DISTRIBUTION OF PRECIPITABLE WATER VAPOR OVER THE OCEANS AND INFERENCE OF BOUNDARY LAYER STRUCTURE

C. Prabhakara, *Goddard Space Flight Center, Greenbelt, Maryland 20771*

ABSTRACT

Over the oceans satellite infrared spectral measurements in the $18\ \mu\text{m}$ water vapor band and the $11\ \mu\text{m}$ window region have been used to derive precipitable water vapor, w , in the atmosphere and the sea surface temperature, SST. Seasonal maps of w on the oceans derived from these data reveal the dynamical influence of the large scale atmospheric circulation. With the help of a model for the vertical distribution of water vapor, the configuration of the atmospheric boundary layer over the oceans can be inferred from w when the information of SST is combined. The gross seasonal mean structure of the boundary layer inferred in this fashion reveals the broad areas of the trade wind inversion and the convectively active areas such as the intertropical convergence zones.

INTRODUCTION

The general circulation of the atmosphere displays some important climatological features over the oceans such as the subtropical anticyclones and the intertropical convergence zones. The circulation of the oceanic subtropical anticyclones extends to about 40°N and 40°S in the respective hemispheres. The equatorward trade winds associated with these anticyclones are instrumental in transporting the water vapor to intertropical convergence zones and thereby help to maintain the directly driven Hadley circulation in the tropics (Riehl, et al., 1954; and Malkus, 1956). A salient feature of the trade wind circulation in the lowest layers of the atmosphere is the trade wind inversion which is produced as a consequence of the large scale dynamics of the subtropical anticyclones. Furthermore the base of this inversion is found to slope upward along the down stream (NE to SW in the northern hemisphere) in response to the joint influence of small convective motions and large scale subsidence (Mak, 1976).

The intertropical convergence zone is produced by the convergence of trades in the low levels. The vertical rising motion generated by the surface convergence leads to significant upward transport of water vapor making the lower layers of the troposphere very humid.

The importance of the sea surface temperature (SST) anomalies has been pointed out by several studies (see for ex. Namias, 1978). The association between these anomalies and the strength of the trades in the Pacific Ocean has been revealed in a study by Reiter (1978).

From the above discussion we see that remote sensing of SST and the stratification of the atmosphere in the first few kilometers above the ocean surface could be valuable for investigating the regional and seasonal climate.

REMOTE SENSING

The SST can be estimated from a method developed by Prabhakara et al. (1974) called the 'split window technique' which requires two radiance measurements in the $11\ \mu\text{m}$ window region. Applying this method to the Nimbus 4 Infrared Interferometer Spectrometer (IRIS) data, seasonal mean maps of SST for three seasons (1. April, May and June; 2. July, August and September; and 3. October, November and December of 1970) have been derived. The cloud contamination in the data is eliminated by means of the following criterion: When the measured $11\ \mu\text{m}$ brightness temperature exceeds 290° , 285° and 280° in the latitudinal zones $0^\circ - 20^\circ$, $20^\circ - 30^\circ$ and $30^\circ - 45^\circ$ respectively the data are accepted as cloud free.

Over the oceans the precipitable water vapor w can be remotely sensed when a radiance measurement in the $18\ \mu\text{m}$ water vapor band is available. The difference between the surface temperature and the brightness temperature T_{18} in the $18\ \mu\text{m}$ band gives a measure of w . In Figure 1 the w estimated from Nimbus 4 IRIS data

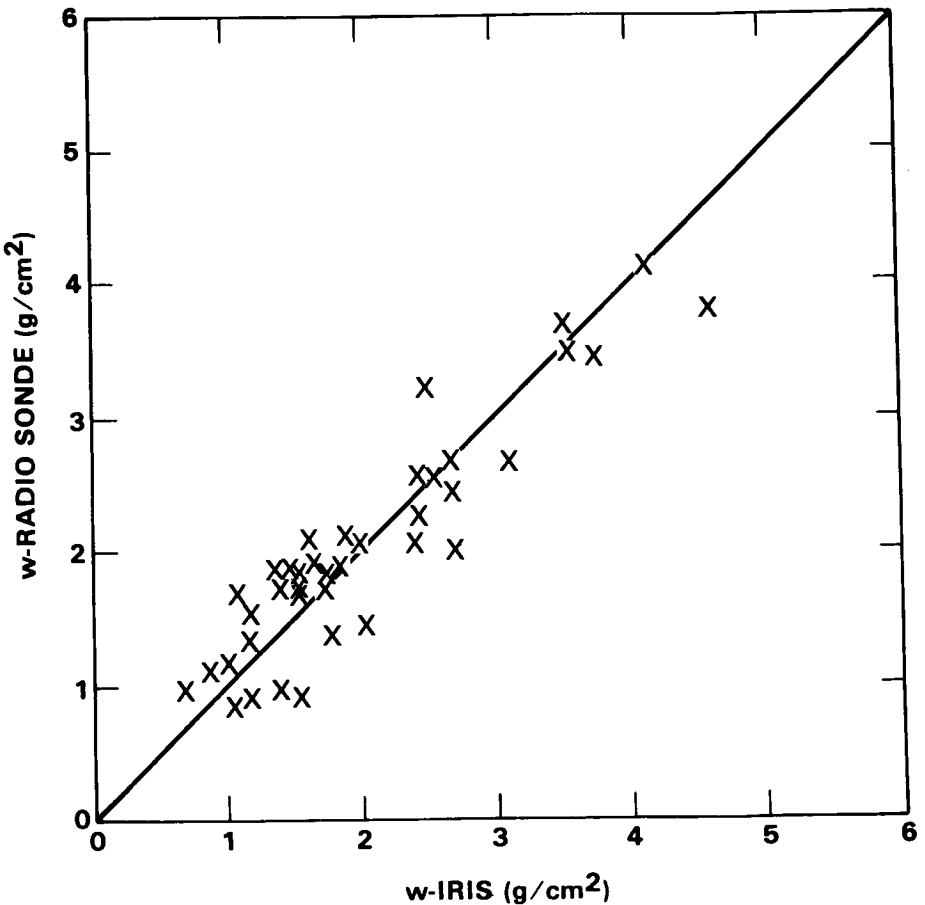


Fig. 1—Comparison between the water vapor content derived from the Nimbus 4 IRIS data and the water vapor content obtained from radiosonde data.

and the corresponding radiosonde measurements taken from 41 ship stations is compared. The standard error of estimation in w is about 0.4 g/cm^2 . With the help of this method the w over the global oceans is estimated for the three seasons mentioned earlier. A map of the w over the oceans from about 45°N to 40°S for the period April, May and June 1970 derived in this fashion is shown in Figure 2.

The remotely sensed SST and w over the oceans can be used to infer the stratification of the atmosphere as shown in a study by Prabhakara et al., 1978. This is possible because on the average the vertical distribution of water vapor in the atmosphere above water bodies can be represented with a simple model. Then some average value of precipitable water \bar{w} can be associated to a given surface temperature. The departure of the measured w from the corresponding \bar{w} relates to the atmospheric stratification in the boundary layer. For instance w exceeds \bar{w} when convective conditions, such as ITCZ, are present. When w is less than \bar{w} stable conditions of inversions prevail.

The excess or deficit of w as mentioned above has been derived from IRIS data and a map of it is shown in Figure 3 for April, May and June 1970. The gross characteristics of the boundary layer over the oceans are seen in this map. The hatched areas showing excess of w correspond to ITCZ and the regions associated with the trade wind inversion on the north and south Atlantic and Pacific oceans as well as the Arabian sea are clearly seen.

REFERENCES

- Mak, M. K., A Model Study of the Downstream Variation of the Lower Trade-Wind Circulation, *Tellus*, Vol. 28, n. 2, 97-107, 1976.
- Malkus, J. S., On the Maintenance of the Trade Winds, *Tellus*, Vol. 8, n. 3, 335-350, 1956.
- Namias, J., Multiple Causes of the North American Abnormal Winter 1976-77, *Mon. Wea. Rev.*, Vol. 106, N. 3, 279-295, 1978.
- Prabhakara, C., G. Dalu, and V. G. Kunde, Estimation of Sea Surface Temperature from Remote Sensing in the 11-13 μm Window Region, *J. Geophys. Res.*, Vol. 79, 5039-5044, 1974.
- Prabhakara, C., G. Dalu, R. Lo, and N. R. Nath, Inference of The Boundary Layer over the Oceans from Satellite Infrared Measurements, NASA Technical Memorandum 79653, pp. 55, 1978.
- Reiter, E. R., The Interannual Variability of the Ocean-Atmosphere System, *J. Atmos. Sci.*, Vol. 35, n. 3, 349-370, 1978.
- Riehl, H., *Tropical Meteorology*, McGraw-Hill Book Co., Inc., New York, pp. 392, 1954.

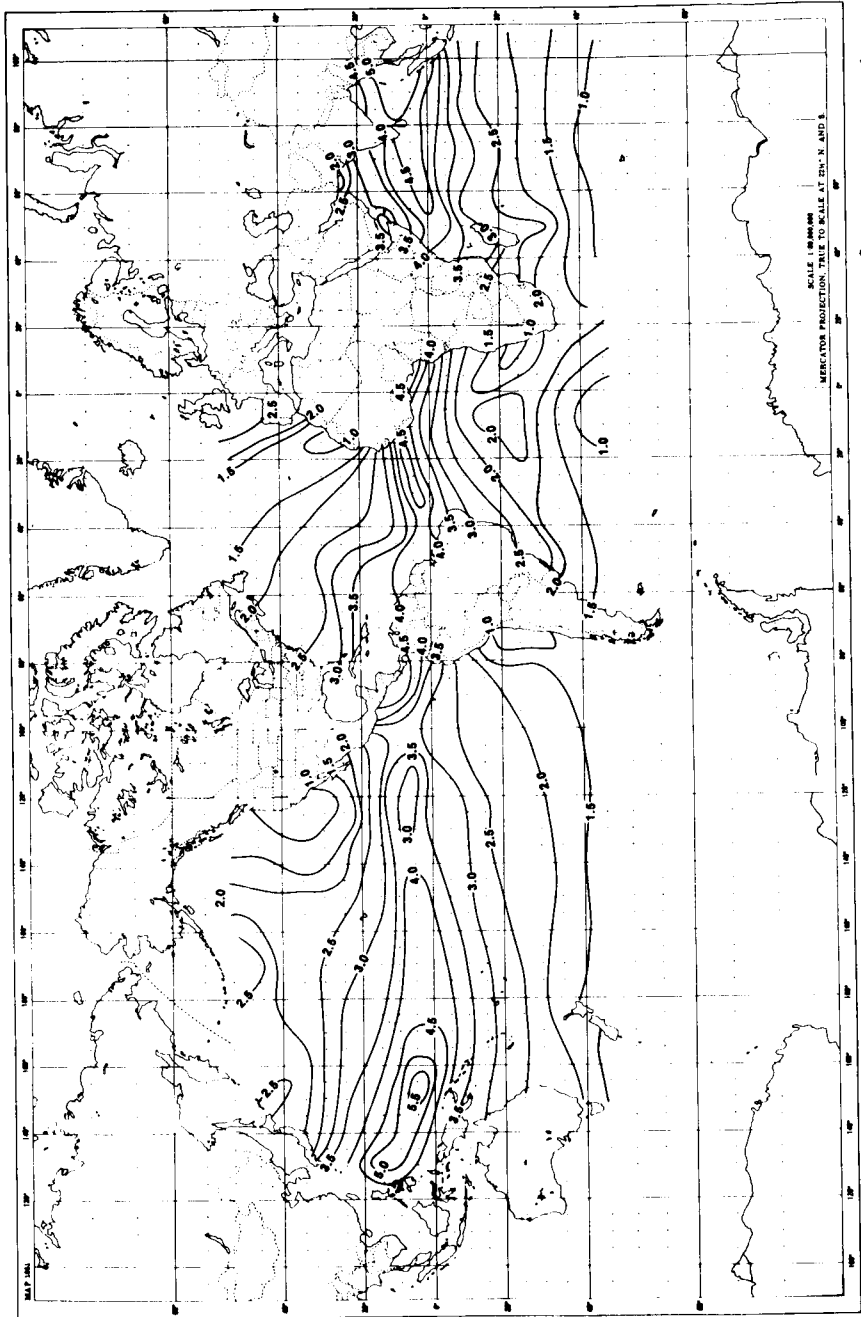


Fig. 2—Distribution of the total water vapor content (g/cm^2) over the global oceans (50°N to 40°S) derived from the Nimbus 4 IRIS data over the period April, May and June 1970.

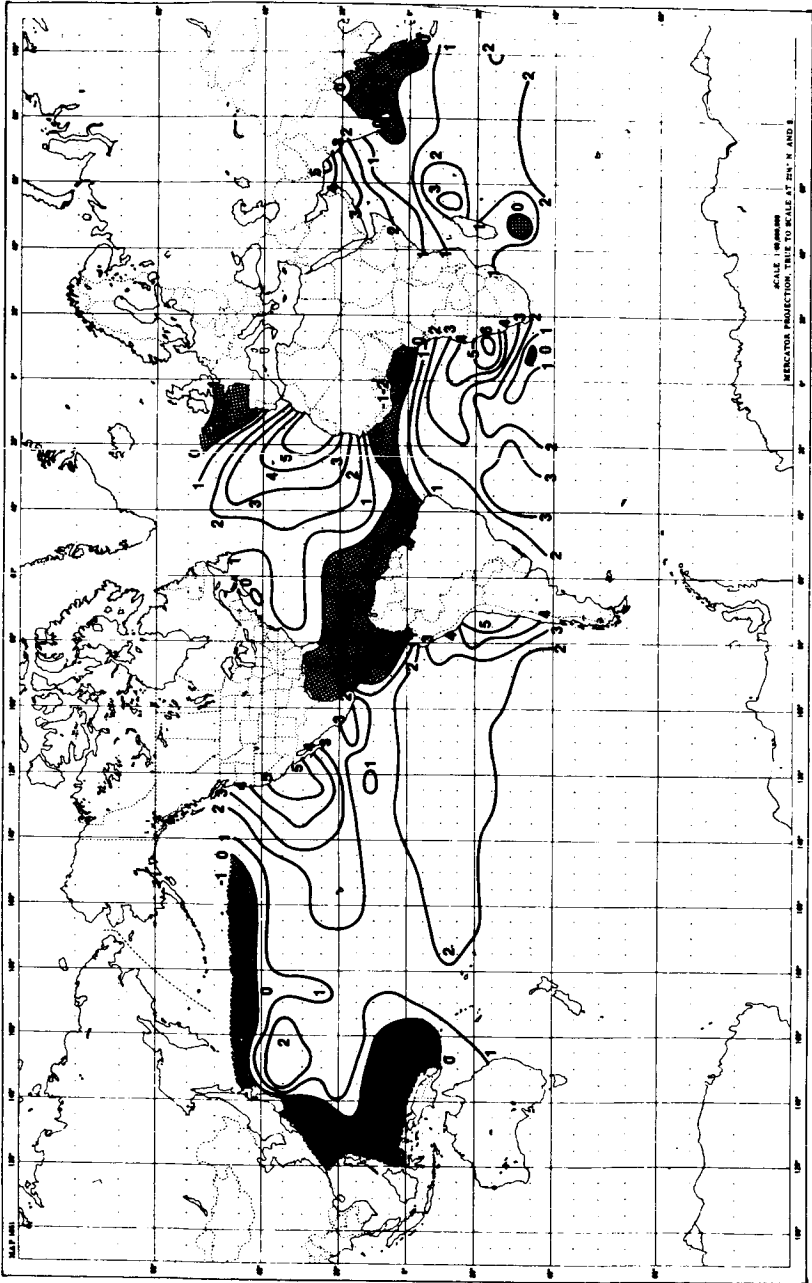


Fig. 3—Distribution of the index, $(\bar{w} - w)\bar{w} \times 10$, over the global oceans derived from the Nimbus 4 IRIS data for the period April, May and June 1970. Positive value of this index gives a measure of the temperature increase from bottom to top of trade wind inversion in $^{\circ}\text{C}$. Negative values of the index are shown by shading.