P1.4 STRUCTURE OF THE LOWER TROPOSPHERE OVER THE PACIFIC OCEAN: INFORMATION GAINED FROM AIRS OBSERVATIONS

Hengchun Ye*
California State University, Los Angeles, CA
E. J.Fetzer, E. T. Olsen, A. Eldering, S. Granger, L. Chen, B. H. Lambrigtsen, E. Fishein, S.-Y. Lee, B. Kahn, A. Braverman
JPL, Pasadena, CA

1. INTRODUCTION

We have very limited information on atmospheric conditions over oceans compared to those over land surfaces where most radiosonde observations are located. Studies have revealed some unique characteristics of marine atmospheric conditions near coastal shores or surrounding tropical islands where radiosondes have been launched to collect data for specific research campaigns, including the trade wind inversion that caps cumulus clouds over tropical oceans (Schubert et al. 1995), the deep inversion layer associated with stratus clouds near the coastal west coast (Fetzer et al. 2004; Klein and Hartmann 1993; Kloesel and Albrecht 1989), and the shallow marine mixing layer (Johnson et al. 2001). All these characteristics are reflected in vertical profiles of temperature and humidity conditions in the low troposphere. However, constrained by difficulties of gathering data, most of these studies are limited to either a specific geographic location or a short time period (a few days).

With the development of satellite technology and increasing satellite observations, high resolutions of atmospheric profiles have become available on a daily basis. This makes systematic and large-scale study of marine atmospheric conditions a reality. This study shows examples of using Atmospheric Infrared Sounders (AIRS) observations to reveal lower tropospheric atmospheric characteristics over the Pacific Ocean.

2. DATA

Atmospheric Infrared Sounder (AIRS) is designed to measure atmospheric temperature and humidity profiles and other atmospheric and surface variables at a very high resolution by using multi-channel infrared and microwave radiances. It is mounted on the EOS-AQUA satellite launched on May 4, 2002 and is made up of three instruments: AIRS (2378 spectral channels and 4 visible and near-infrared), AMSU-A (15 channel microwave temperature), and HSB (4 channel microwave humidity) (Aumann et al. 2003). The AIRS infrared spatial resolution is 13.5 km from the nominal 705.3km orbit and the visible/near infrared (Vis/NIR) spatial resolution is approximately 2.3km.

Validation of data over regions between 50ºS-50ºN have shown that temperature in the troposphere has accuracies of 1K over 1km-thick layers under both clear and cloudy (up to 70% cloud cover) conditions compared to the matching radiosonde observations, while the accuracy of moisture profiles exceed that obtained by radiosondes (Fetzer et al. 2003; Fishbein et al. 2003).

AIRS's standard products consist of 28 layers of standard atmosphere from 1100mb-0.1mb and support products have 100 layers with finer vertical resolutions from 1100mb-0.0161mb. In this study, we use AIRS's support products of lower atmospheric (at 515.719971mb layer and below) temperature and humidity profiles over the tropical Pacific Ocean between 35ºS-35ºN to study their spatial pattern of atmospheric characteristics for the two days of January 19, 2003 and May 11, 2003 respectively (during the descending track for both days). There are 22 atmospheric layers from the surface to about 516mb from AIRS in the support files. In addition, on January 19, the ascending day's track is also analyzed and compared with the descending day's track to check for consistency and diurnal variations

3. METHODS

First, vertical temperature profiles are examined to identify the region and the height of temperature inversion for these two selected days. Each temperature profile (over individual footprint) is examined to find the pressure level where inversion starts and ends. The top and bottom pressure level are plotted across the study region. This reveals the location and depth of the temperature inversion on a particular day.

Second, we use an atmospheric relative dry-wet index to examine the distribution of vertical change in wetness or dryness throughout the lower troposphere. The index is the saturation pressure level (P0; the level where uprising air from its original level starts saturation) subtracted by the pressure of the original level used by Betts and Albrecht (1987) in their atmospheric stability study. The larger the index value, the drier the air is (further away from saturation). The index value is calculated for each of the atmospheric layers to derive the vertical profile of the relative dry-wetness condition for each footprint. In general, it is believed that the index value reaches minimum right beneath the trade wind inversion due to subsiding dry and warm air over a relatively well-mixed moist marine air (Betts and Albrecht 1987). On the other hand, peak index value (near zero) suggests a moisture atmospheric layer close to saturation.

---

*Corresponding author: Hengchun Ye, California State University, Los Angeles, Dept of Geography and Urban Analysis, Los Angeles, CA 90032-8222; e-mail: Hengchun.Ye@calstatela.edu

Third, principle component analysis (PCA) is applied to the 22 layers of the relative dry-wet index values for all footprints over the study region. This method is used to reduce numerous footprint values into a few major geographical patterns where similar vertical structures of the index value are found.

4. RESULTS

4.1 Temperature Profiles

Based on January 19, 2003's temperature inversion height map (Figure 1), the lowest inversion layer of around 1000mb is found over the Gulf of California and a few places over the equatorial tropical Pacific ocean. The deepest inversion layers are found over 25ºN-30ºN and 180ºE. An intermediate depth of inversion layer is found over the southern coast of South America.

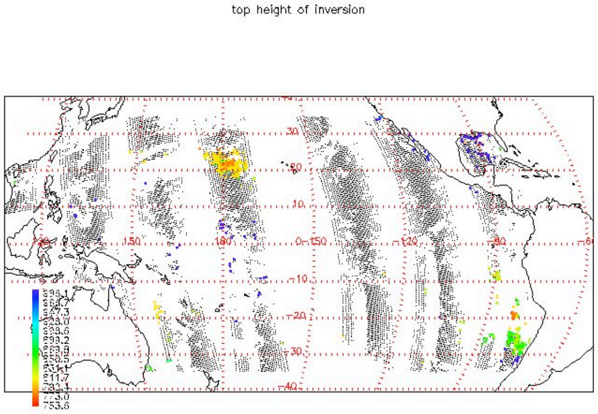


Figure 1. The top pressure layer of observed temperature inversion in January 19, 2003.

On May 11, 2003,the deepest inversion is found over the west coast of southern South America. A wide spread of intermediate depth inversion layer appears near the coast of Baja, Mexico and southern California. Very shallow inversion appears over 30ºN-35ºN, east of 180ºE.

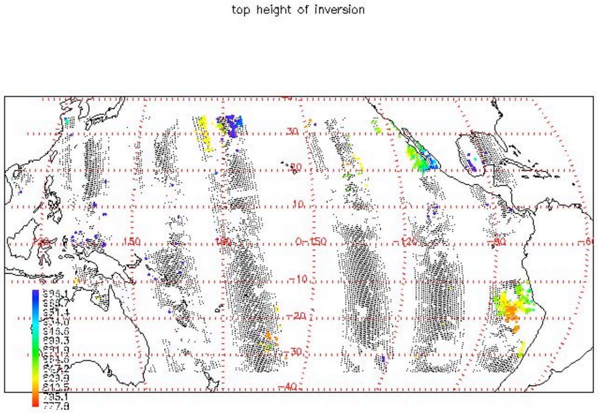


Figure 2. The top pressure layer of observed temperature inversion on May 11, 2004.

4.2 PCA Results

PCA analyses produced three major EOFs (identified by eigenvalues larger than 1) in each of the two days. For January 19, 2003, the three PCs explain 65.6%, 23.2%, and 5.7% of the total variance of all footprints respectively. For May 11, 2003, the three PCs explain 68.3%, 22.2%, and 5.3% of the total variance of all the footprints respectively. The vertical profiles for each PC are very similar between these two days. The first PC shows that a minimum index value occurs near an atmospheric layer between 700 mb and 750 mb (Figure 3, and Figure 4). The dark blue color indicates high loading of PC1, or dry air in the layer around 700mb-750mb; the red color indicates large negative loadings of PC1, or wet air in this layer. The dry layer suggests an inversion cap above and the moist layer suggests well mixed or some cloud presence in this layer. The wet area (red) seems to coincide with the inter-tropical convergent zone (ITCZ) on both days. Dry areas are found on the west coast of southern California and Baja Mexico and other localized places away from the ITCZ.

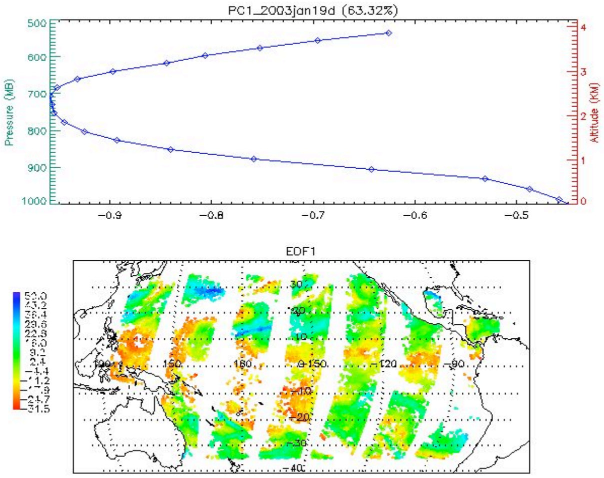


Figure 3. The vertical profile of PC1 (upper panel) and its loading (bottom panel) for January 19, 2003.

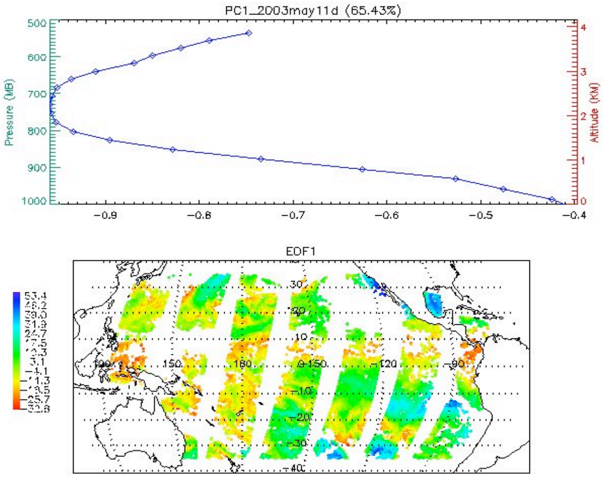


Figure 4. The same as figure 3, except for May 11, 2003.

PC2 represents a vertical profile with a low index value occurring near the surface around 950mb (Figures 5 and 6). This near surface dry layer (blue) is found over the west coast of Mexico and southern California and the wet layer (red) is found scattered over the central tropical Pacific Ocean and changes on a daily basis.

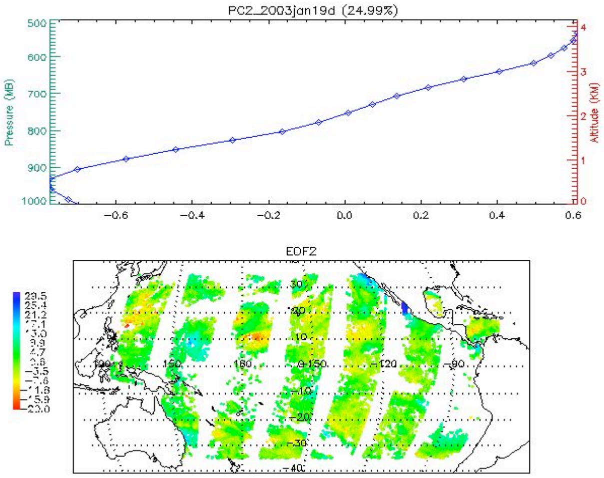


Figure 5. Vertical profile of PC2 and its spatial loading for January 19, 2003.

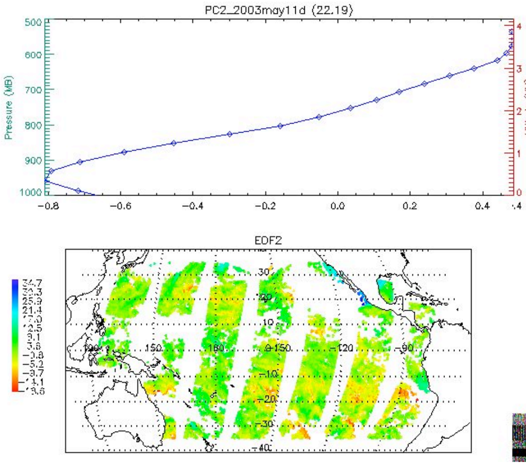


Figure 6. The same as Figure 4, except for May 11, 2003.

PC3 represents a vertical profile with a low index value occurring near 800-850mb (Figures 7 and 8). This PC explains very small variability compared to the others. It appears that there are more dry places over January than May days. Similarly, May days have more wet places at this atmospheric layer than January days.

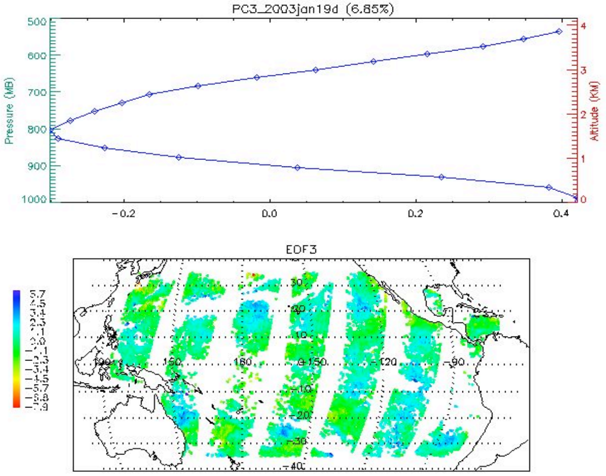


Figure 7. Vertical profile of PC3 and its spatial loading for January 19, 2003.

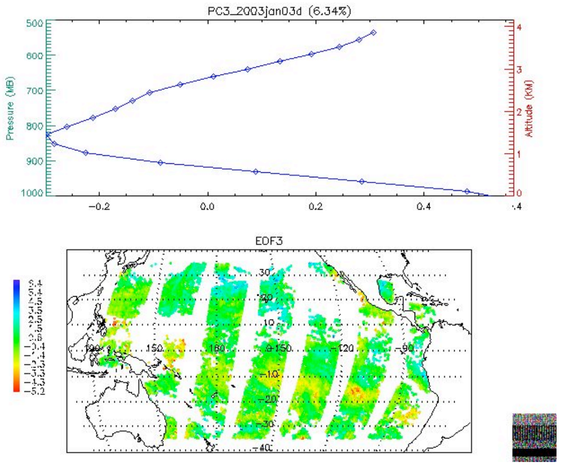


Figure 8. The same as Figure 7, except for May 11, 2003

To compare for consistency and to examine diurnal variations, PCA is also applied to footprints on the ascending track of January 19, 2003. The results are very similar to the descending track. The dominant variability is explained by PC1 (65.65%), which represents dry-wetness over the 700mb-750mb layers. Since the variance explained by this PC is a little higher than that of the descending track, a more dominant pattern during daytime (ascending) than nighttime (descending) is indicated. The negative loading of large values (red) has a very similar geographical distribution over the study area. This further verifies that the largest moisture variations occur over the 700mb-750mb level where ITCZ has the most influence.

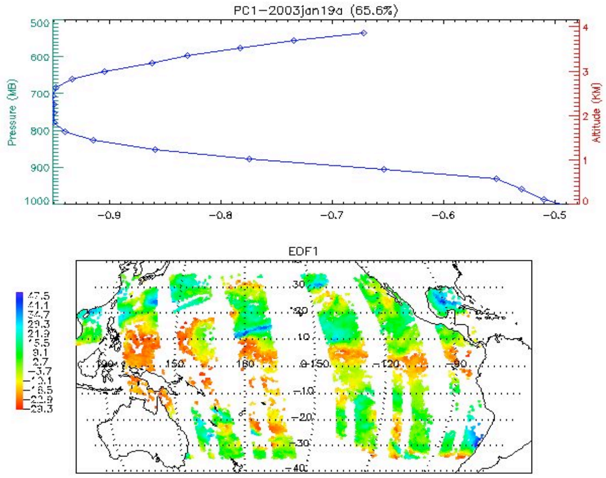


Figure 9. Vertical profile of PC1 during ascending track on January 19, 2003.

PC2 is also very similar to that of the descending track of the same day. The dry layer over 950mb is found over the west coast of Mexico and southern California; the wet areas are scattered over the central tropical Pacific Ocean. The variance explained by this PC is smaller and the absolute loading values are also smaller compared to the descending track, suggesting that the contrasts between dry and wet over this surface layer is more significant during nighttime (descending).

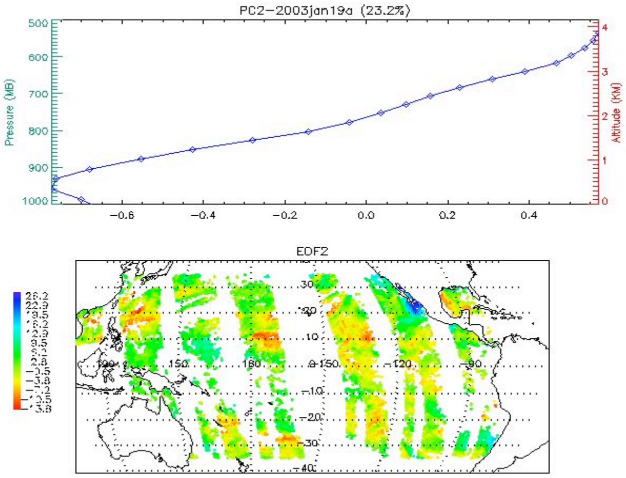
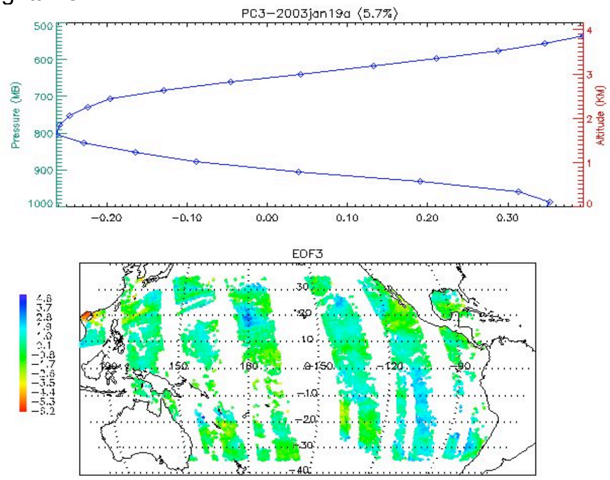


Figure 10. Vertical structure of PC2 and its spatial loading for ascending track of January 19, 2003.

PC3 of the ascending track on January 19, 2003 describes dry-wetness around the 800mb layer. This PC3 has a smaller variance compared to the descending track. This suggests that moisture contrasts at this layer are smaller during daytime than at nighttime.



5. SUMMARY

This study uses AIRS data to examine the tropospheric characteristics at both horizontal and vertical dimensions simultaneously at two randomly selected days. Results reveal different heights of inversions over different regions over the tropical Pacific Ocean. In addition, we discovered three major atmospheric layers where moisture contrasts are largest: the 700mb-750mb layer, the 950mb layer, and the 800-850mb layer. The 700mb-750mb layer is the most significant atmospheric layer regarding dry-wetness characteristics. This layer captures the ITCZ moisture condition and also suggests that moisture contrasts are slightly stronger during spring than winter and stronger during daytime than nighttime.

On the other hand, the near surface layer dry-wetness contrast is weaker during northern spring than winter and weaker during daytime than nighttime. Dry-wetness in the 800mb-850mb layer has the least variability compared to the other two layers above and below. No significant seasonal variation is found in this layer. However, nighttime seems to have larger spatial contrasts than daytime.

Since conclusions are based on only two day's data (three trackings), results may be subject to change as more days are included. This study is just a showcase of an application of AIRS data in scientific research. With the accumulation of over three years of AIRS data, its contribution to the scientific community will be significant in the near future.

6. ACKNOWLEDGEMENTS

The first author is supported by the NASA summer Faculty fellowship program for this research project. We highly appreciate JPL for providing the research facility to the authors.

7. REFERENCES

Aumann, H. H., M. T. Chahine, C. Cautier, M. D. Goldberg, E, Kalnay, L. M. McMillin, H. Revercomb, P. W. Rosenkranz, W. L. Smith, D. H. Staelin, L. L. Strow and J. Susskind, 2003: AIRS/AMSU/HSB on the Aqua mission: design, science objectives, data products and processing system, IEEE Transactions Geosciences and Remote Sensing, 41, 253-264.

Betts, A. K., and B. A. Albrecht, 1987: Conserved variable analysis of the convective boundary layer thermodynamic structure over the Tropical Oceans. J. of Atmos. Sci. 44, 83-99.

Fetzer, E. J., L. McMillin, D. Tobin, H. H. Aumann, M. R. Gunson, W. W. McMillan, D. E. Hagan, M. D. Hofstadter, J. Yoe, D. Whiteman, J. Barnes, R. Bennartz, H. Vömel, V. Walden, M. Newchurchm P. Minnett, R. Atlas, F. Schmidlin, E. T. Olsen, M. Goldberg, S, Zhou, H. Ding, W. Smith, Sr., H. Revercomb, 2003b: AIRS/AMSU/HSB validation, IEEE Transactions Geosciences and Remote Sensing, 41, 418-431.

Fetzer, E., J. Teixeira, E. Olsen, 2004: E. Fishbein, Satellite remote sounding of atmospheric boundary layer temperature inversions over the subtropical eastern Pacific. Geophys. Res. Lett., vol. 31, L17102, doi:10.1029/2004GL020174.

Fishbein, E., C. B. Farmer, S. L. Granger, D. T. Greggorich, M. R. Gubson, S. E. Hannon, M. D. Hofstadter, S.-Y. Lee, S. S. Leroy, and L. L. Strow, 2003: Formulation and Validation of simulated data for the Atmospheric Infrared Sounder (AIRS), IEEE Transactions Geosciences and Remote Sensing, 41m 314-329.

Klein, S. A., and D. L. Hartmann, 1993: The seasonal cycle of low statiform clouds. J. Climate, 6, 1587-1606.

Klosesl, K. A., and B. A. Albrecht, 1989: Low-level inversions over the tropical Pacific–thermodynamic structure of the boundary layer and the above-inversion moisture structure. Mon. Wea. Rev., 17, 87-101.

Johnson, R. H., P. E. Ciesielski, and J. A. Coturone, 2001: Multiscale variability of the atmospheric mixed layer over the western Pacific warm pool. J. of atmos. Sci., 58, 2729-2750.

Schubert, W. H., P. E. Ciesielski, C. Lu, and R. H. Johnson, 1995: Dynamical adjustment of the trade wind inversion layer. J. of Atmos. Sci., 52, 2941-2952.