Characteristics of the Low-Level Temperature Inversion at the North Slope of Alaska on the Base of Microwave Remote Sensing Data

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Introduction

The structure of the Polar atmosphere has been of interest to scientists since 1906. The presence of the stable planetary boundary layer (PBL) is related to peculiarities of high latitude energy balance. There are three main inversion types: radiation inversion, melting inversion, and elevated inversion (due to advection or subsidence) (Busch et al. 1982).

In Barrow, Alaska, during the winter period from January to April, 85% of radiosonde soundings detected the first type, and only about 10% elevated inversion (Busch et al. 1982) (not more than 25% according to Kahl [1990]). Usually radiation inversions are connected with a downward turbulent flux of sensible heat at the surface and thus have negative net radiation. All those inversions are the surface inversion. The analysis of radiation climate at Barrow (Maykut et al. 1973) shows that, between October and April, the radiation balance is dominated by the net longwave radiation resulting in its negative values during these months. Melting is the other surface type inversion typical for summer (20% to 30%). Lifted inversions are controlled by thermodynamic budgets of the layers of concern and by the surface energy fluxes.

Historically the determination of temperature inversion features (height of inversion base, inversion depth, and temperature difference across the inversion) at the North Slope of Alaska was based on twice-daily radiosonde sounding data from the Barrow and Barter Island stations. Since 1998, after installation of MTP-5 (microwave temperature profiler) at the Barrow station, it is now possible to obtain more detailed information about the dynamics of the temperature inversion in the Arctic. MTP-5 can measure temperature profiles up to 600 m each 15 minutes, which gives the possibility for investigation of temperature inversion dynamics.

Data of Comparisons

Before installation at the Barrow station, MTP-5 had been tested in Boulder, Colorado. The comparisons with the meteotower and Radio Acoustic Sounding System (RASS) confirm high accuracy of the microwave device (Westwater et al. 1997; Kadygrov et al. 1996, and 1998). Figure 1 presents the mean square root of the three methods. These analyses have been provided by Westwater et al. 1999.

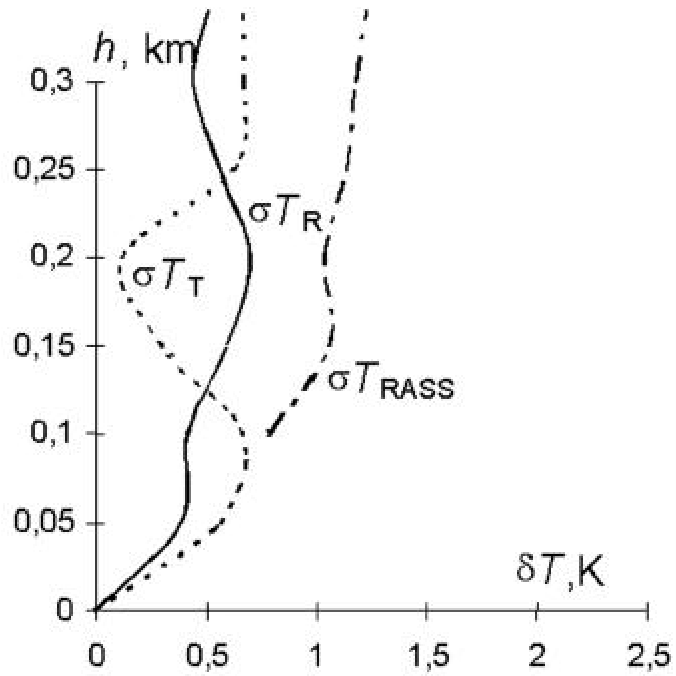

Figure 1. Mean square root of three methods (σT_R-microwave, σT_T-meteotower, σT_{RASS}-RASS).

To verify accuracy estimates at high latitude conditions, MTP-5 data were compared with in situ radiosonde data at the Barrow site. An example of these comparisons is shown in Figure 2.

Elevated Inversions Sounding

The algorithm of temperature recovery is connected with integration over the antenna beam of 6° aperture. The beam averaging allows one to obtain specific local features that are not significant for the mesoscale thermodynamic of PBL. However, integration limits the possibility of detecting elevated inversion. In fact, the device installed at Barrow can detect elevated inversion with a base from 100 m to 200 m. That means that because of the Kahl (1990) analyses of Barrow PBL, we can registrate ≈ 59% of lifted inversions. Therefore, only about 5% to 6% of inversions at Barrow are out of our detectable range. This amount is negligible because, for elevated inversion, the composition of the atmosphere

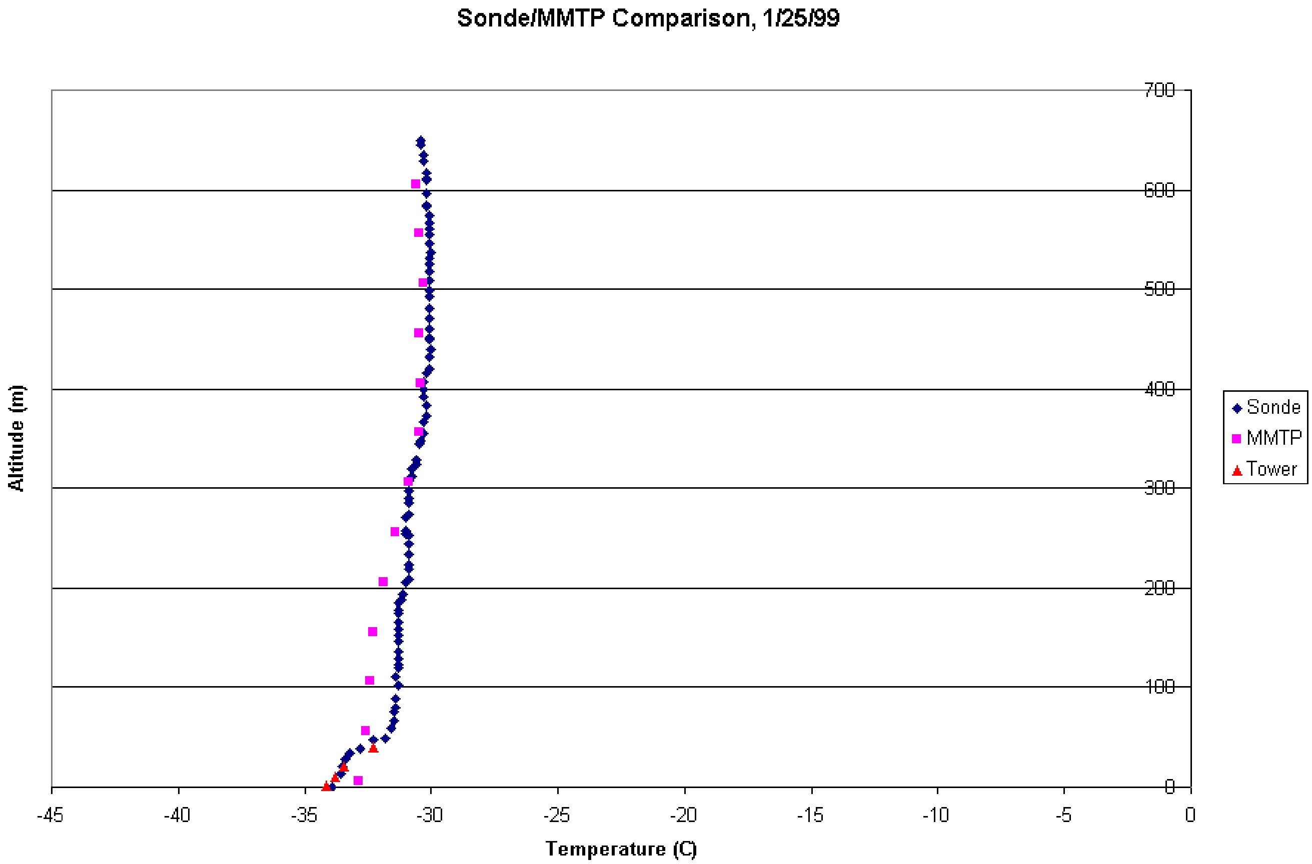

Figure 2. Comparisons with radiosonde meteotower at Barrow.

below the inversion base is determined by local sources (Bridgman et al. 1989); so research of global Arctic problems not connected with specific Barrow micro climatic traces are possible and well supported by MTP data. Figure 3 demonstrates cases of elevated inversions. Figure 4 demonstrates the case of high-based elevated inversion.

PBL Dynamics Analysis

The regular MTP-5 data (each 15 minutes) gave an opportunity to obtain a dynamic weight of different processes in the formation of surface inversion.

An example of the intrusion of cold air from the upper layer to PBL makes it possible to estimate the speed of such a process (Figure 5).

$$\tilde{u} = \frac{600}{d\tau} \sim 10\mathrm{m/min}$$

Cold air advection occurs below the inversion, while the stabilization process of PBL higher than 250 m shows that the mixing layer height is nonstationary (Figures 6 and 7).

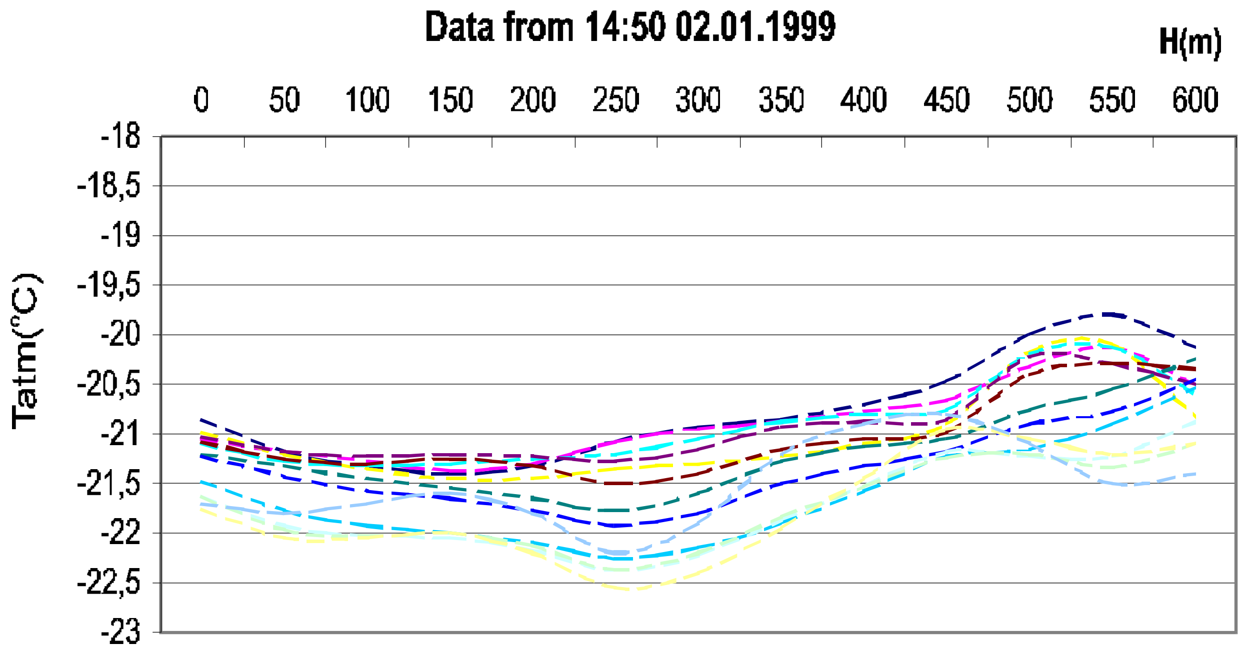

Figure 3. Elevated inversions at Barrow.

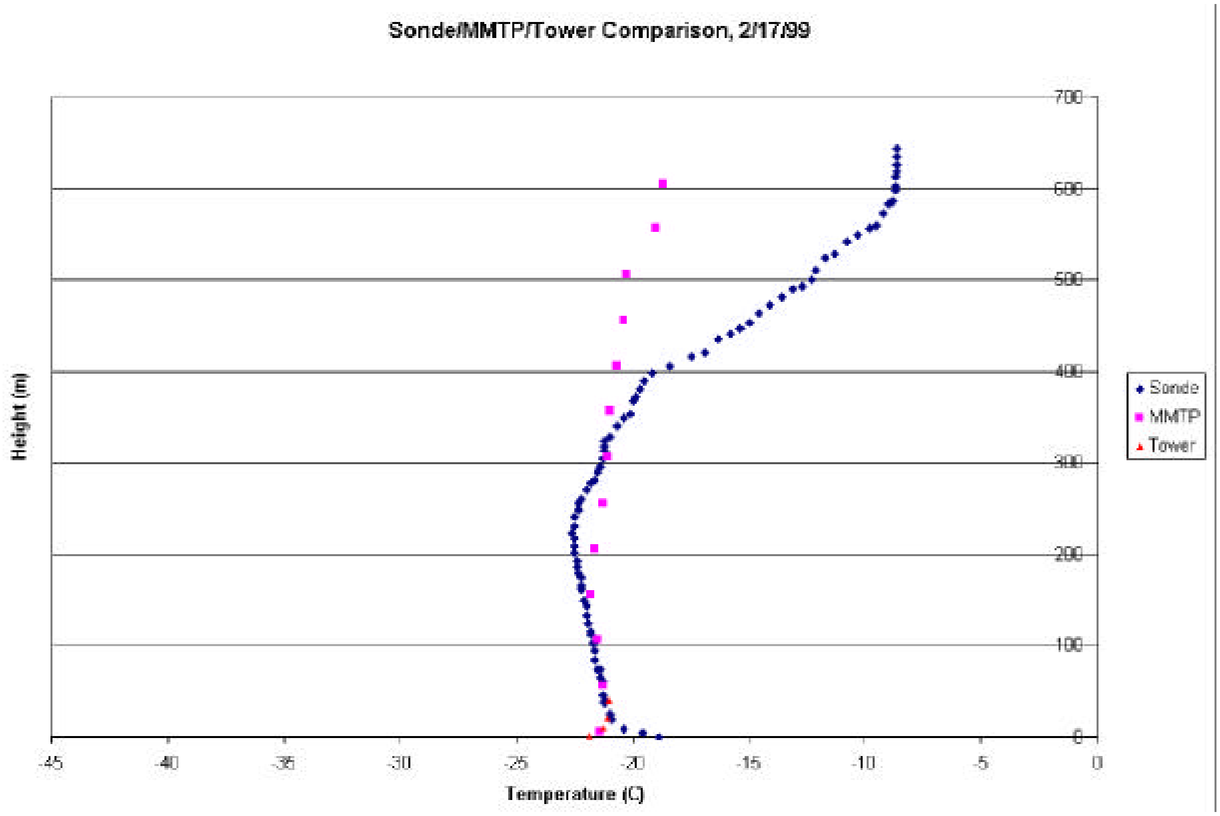

Figure 4. Comparisons with radiosonde meteotower at Barrow nondetected inversion.

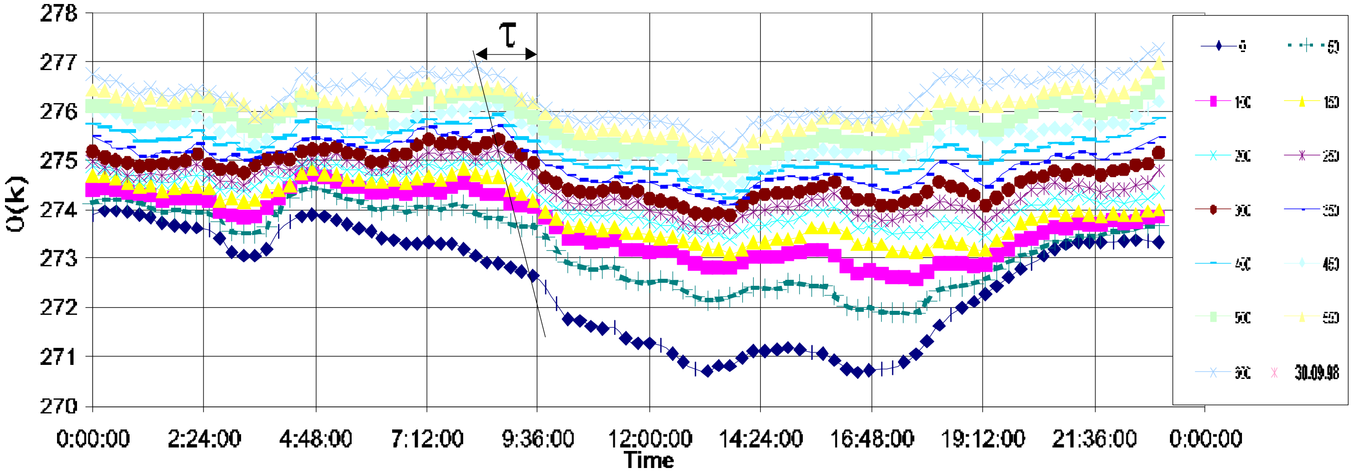

Figure 5. Time dependence of temperature on different altitudes.

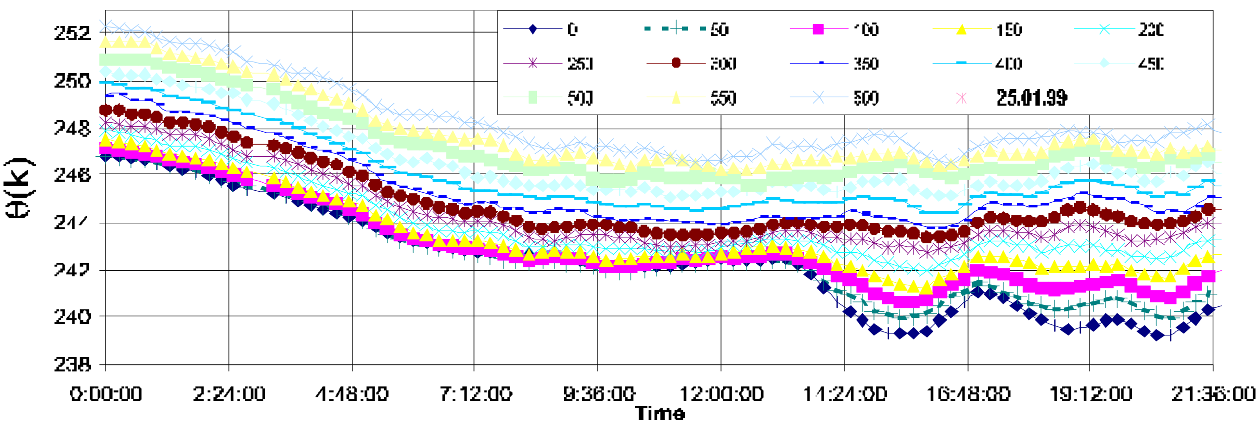

Figure 6. Cold air advection.

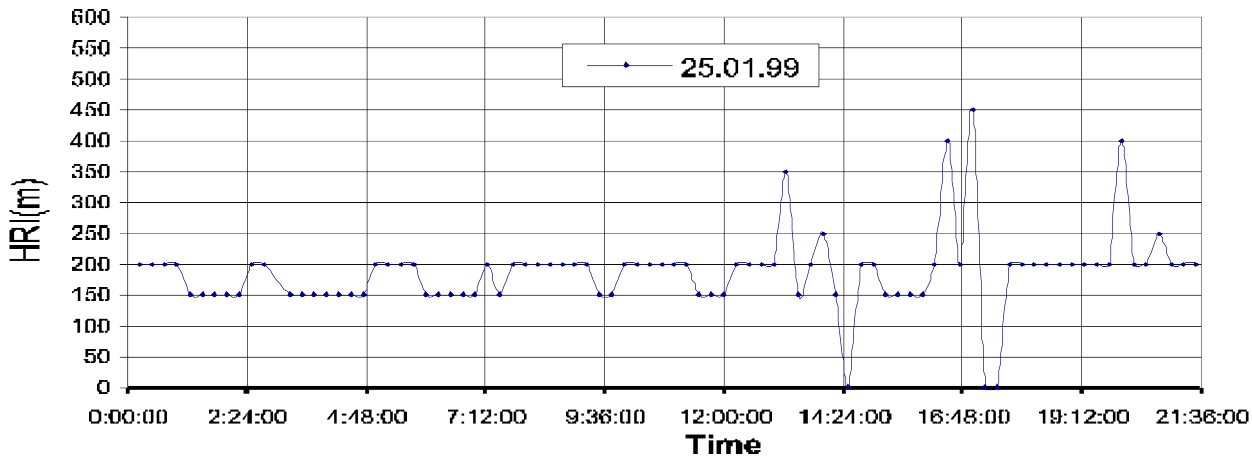

Figure 7. Dynamics of mixing layer height while cold air advection.

Summary

- The transient nature of inversion characteristics between radiosonde soundings does not provide the knowledge of diurnal variations of the PBL thermal structure.

- The continuous remote sensing measurements of PBL temperature profiles by MTP-5 gives a new possibility for study of temperature inversion dynamics in the Arctic.

- According MTP-5 data in Barrow (Alaskan Arctic coast, 71°18’N; 156° 47’W), from January 25, 1999, to March 11, 1999, relative number of days with low-level temperature inversions was 69.6%, which is in good agreement with radiosonde data statistics.

- Analysis of MTP-5 data at Barrow showed that it could not detect the elevated temperature inversion with the inversion base higher than 400 m. However, such elevated inversions are only at about 5% inversions at Barrow and can be detected by radiosondes or perhaps by active methods.

References

Bridgman, H. A., R. C. Schnell, J. D. Kahl, G. A. Herbert, and E. Joranger, 1989: A major haze event near point Barrow, Alaska: Analysis of probable source regions and transport pathways. *Atmospheric Environment*, **23**, N 11, 2537-2549.

Busch, N., U. Ebel, H. Kraus, and E. Schaller, 1982: The Structure of the subpolar inversion-capped atmospheric boundary layer (ABL). *Arch. Met. Geoph. Biokl., Ser. A*, **31**, 1-18.

Kadygrov, E. N., A. V. Koldaev, and A. V. Troitsky, 1996: Ground-based microwave remote sensing of Arctic atmospheric parameters. *Proc. Int. Radiation Symp.*, 675-678. Fairbanks, Alaska.

Kadygrov, E. N., K. P. Gaykovich, E. R. Westwater, Y. Han, and K. Widener, 1998: Potential performance of boundary layer temperature profile microwave remote sensing: results of field testing at various latitude zones. In *Proceedings of the Eighth Atmospheric Radiation Measurement (ARM) Science Team Meeting*, CONF-97036, pp. 353-357. U.S. Department of Energy, Washington, D.C.

Kahl, J. D., 1990: Characteristics of the low-level temperature inversion along the Alaskan Arctic coast. *Int. J. of Climatol*, **10**, 537-548.

Maykut, G. A., and P. E. Church, 1973: Radiation climate of Barrow, Alaska, 1962-1966. *J. of Appl. Meteor.*, **12**, 620-628.

Westwater, E. R., Y. Han, V. G. Irisov, V. Lenskiy, E. N. Kadygrov, and S. A. Viazankin, 1997: Remote sensing of boundary-layer temperature profiles by a scanning 5-mm microwave radiometer and RASS: A comparison experiment. *Proc. IGARSS'97*, 2093-2096. Singapore.

Westwater, E. R., A. S. Viazankin, K. P. Gaykovich, E. N. Kadygrov, and D. Y. Moiseev, 1999: Radiometric temperature monitoring of atmospheric planetary boundary layer. *Meteorology and Hydrology*, N 3, 59-71.