Reconstruction of the Water Vapor Profiles from the Ground Data

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Introduction

Water vapor plays an important role in the radiation budget of the "atmosphere-underlying surface" system. To solve the problems related to the radiation transfer in the atmosphere, one needs to know both the value of columnar water vapor and the distribution of water vapor over the altitude. It is especially urgent for the lower troposphere.

At the same time, when measuring or calculating the radiative characteristics under the specific atmospheric conditions, sometimes balloon or lidar sounding data is not available. Then it is of interest to develop a method for assessing the water vapor profile from the data of ground-based measurements.

Study Results

In our study, we addressed two important questions.

1. What methods are available to address this problem?
   - It is not difficult to measure humidity in the ground layer, but the use of a priori function for describing the water vapor vertical distribution can lead to significant errors.
   - The spectroscopic method of optical hygrometry is effectively used now for measuring the columnar water vapor.
2. How can we use the data on the columnar water vapor and near-ground humidity for reconstructing the water vapor vertical profile?

To answer these questions, we have analyzed the data of the long-term airborne sounding of the lower troposphere (up to 5 km) obtained over Western Siberia (about 1000 profiles).

High vertical resolution and the bulk of data allowed the study of the autocorrelation matrices of specific humidity. The matrices were calculated for four seasons: winter, spring, summer, and fall (Figure 1).

It is seen that the variations of the near-ground humidity values in summer are well correlated with the values at other altitudes due to the intensive mixing in the vertical direction. In winter, the correlation is significantly lower. The autocorrelation matrices for the bulk of spring data are intermediate between winter and summer. The bulk of fall data is close to the summer one.

We propose a method for reconstructing the vertical profile of humidity, which is based on the correlation of specific humidity values at different altitudes q(H) with its near-ground value q(0), and the columnar water vapor W.

For the first step, the vertical profile q(H) is reconstructed using linear empirical equations of the form:

$$q(H) = K(H)\, q(0) + C(H) \qquad (1)$$

where K(H) and C(H) are the empirical coefficients calculated for each season separately.

For the second step, the vertical profile of the coefficient of correction for the columnar water vapor W is calculated in the following form using the profile $q_{rec}(H)$ reconstructed by Eq. (1):

$$K_W(H) = \frac{1}{W_{rec}} \int_{H-\Delta h}^{H+\Delta h} q_{rec}(h)\,dh \qquad (2)$$

where W_{rec} is the columnar water vapor for the profile of specific humidity reconstructed at the first step.

Then the vertical profile of specific humidity is corrected:

$$q(H) = q_{rec}(H) + K_W(H)\, \Delta W / 2\Delta h \qquad (3)$$

where ΔW is the difference between the measured and reconstructed columnar water vapor is $\Delta W = W_{meas} - W_{rec}$.

Vertical profiles of the errors in reconstructing the specific humidity are shown in Figure 2. As would be expected in analyzing the autocorrelation matrices, using the near-ground value q(0) as an input parameter for the summer bulk of data significantly decreases the errors in reconstruction. For other seasons, as the atmosphere becomes cooler and the exchange becomes less effective, taking into account the columnar water vapor becomes more and more significant for reconstruction of the water vapor vertical profile.

Acknowledgments

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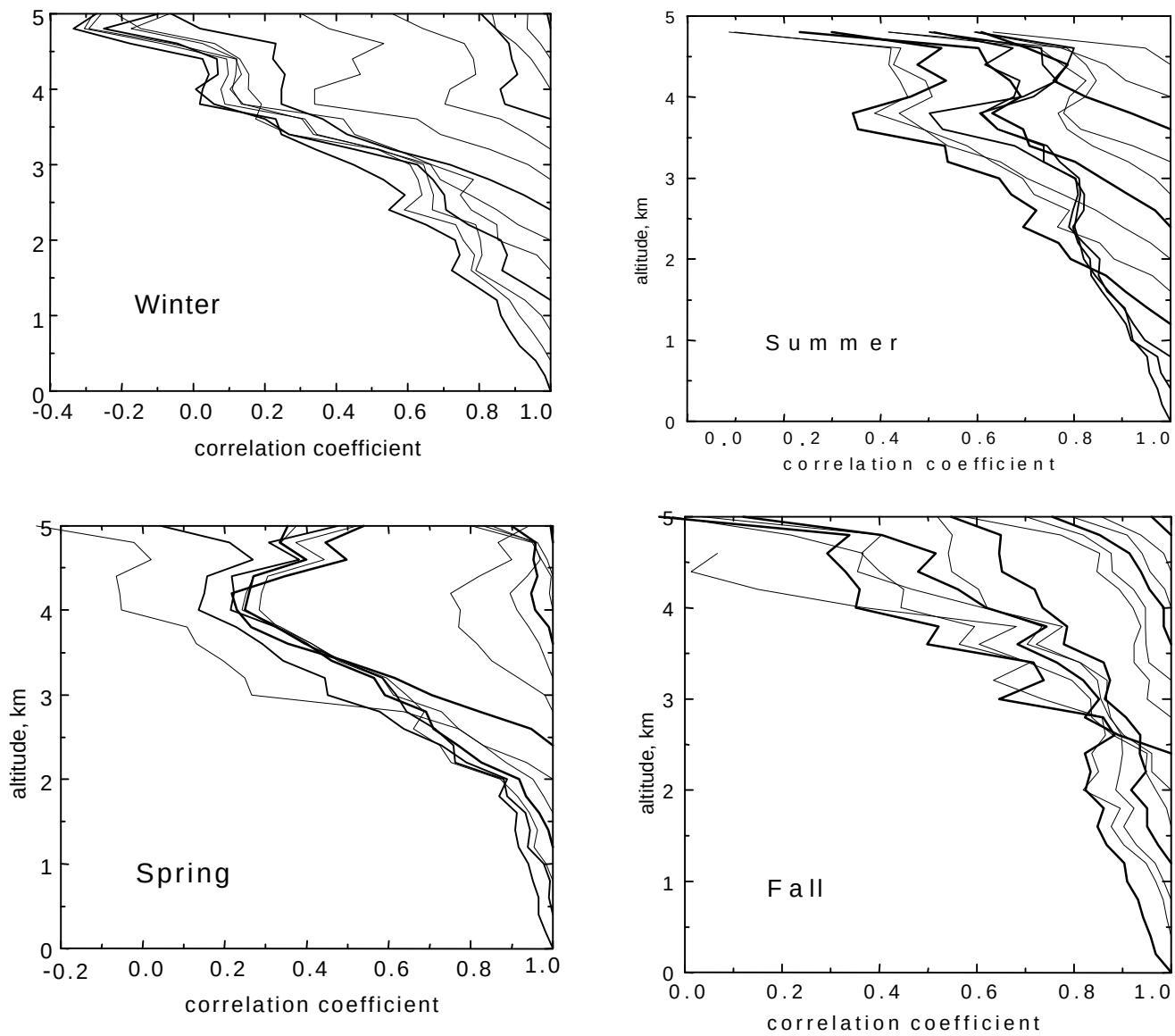

Figure 1. Correlation matrices of specific humidity.

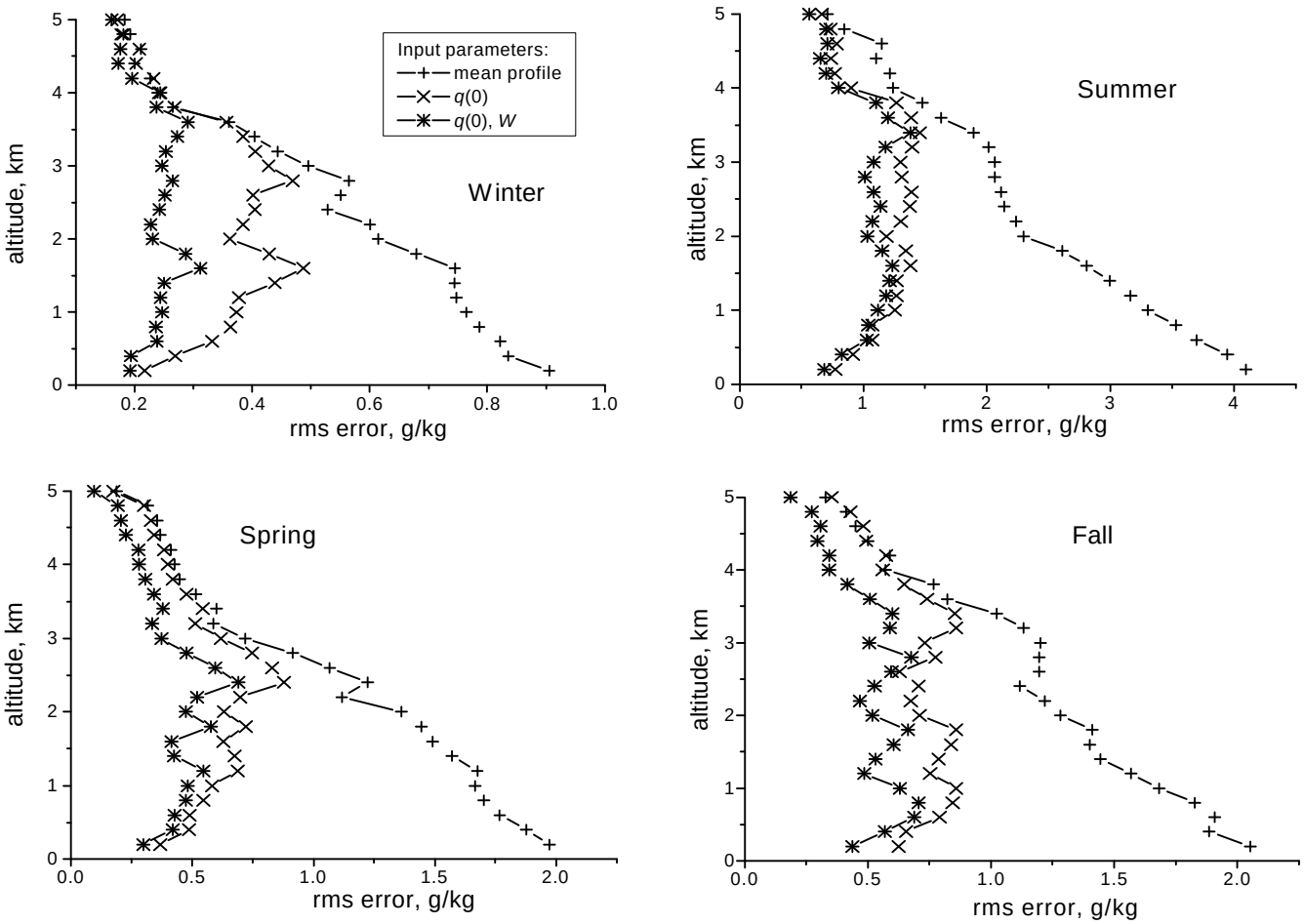

Figure 2. Errors of reconstruction of specific humidity.