Errors in detecting of cloud boundaries for detailed radiosonde profiles

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Last time new detailed upper-air soundings (for example, GPS sounding) with up to several hundred/thousands of observed levels and a distance between levels about 1-3 meters are used for determination of cloud boundaries [Chernykh and Alduchov, 2000; Naud, 2003] by CE-method [Chernykh and Eskridge, 1996; Chernykh et al. 2001].

The main goal of this paper is to pay special attention that detailed profiles may create a problem for various models on the base of derivatives estimations for upper-air variables.

For the very first look such soundings give much better understanding of the observed value profile, including gradient values, comparing to the standard upper-air soundings with 30-80 reported levels. But such detailed profile may create a problem for researcher, because of the current practice of reported values rounding.

Upper air report contains temperature values, rounded to the 0.1 °C, and relative humidity values, rounded to the 0.1%. It is easy to see, the upper estimate for the error of the gradient calculation using two nearest observed temperature values with a current rounding errors for resolution Δh of the profile is

$$\Delta T' = \frac{0.1}{\Delta h}$$

Hence, if $\Delta h = 1\,\mathrm{m}$ (current GPS profiles), then the error of the temperature gradient due to rounding of temperature values is about 0.1 °C/m. Let's compare that value to the standard temperature gradient 0.7 °C per 100 m, i.e. 0.007 °C/m. The error is more than 14 times larger that the gradient itself – 1400% error. It is not acceptable for any task. In the same time, if resolution Δh of the profile is about 100 m, then the error due to rounding is about 0.001 °C/m, what means about 14% of the standard gradient, and it is almost acceptable for many tasks.

It means that for current accuracy of the temperature values in 0.1 °C the resolution of the vertical profile (for any tasks with gradient calculations) should be not less than 100-200 m or even more (what gives the error 14-7%, correspondently, because of the original values rounding for standard temperature gradient).

The problem looks even more serious if anybody will use standard observational errors at every reported height. For example, for the US radiosondes at current time the accuracy of temperature measurements is 0.5 °C from the surface to 20 hPa (and up to 1.0 °C at historical time series (see, Hawson, 1970, Hooper, 1978). But in reality an observational errors are significantly correlates in vertical direction, because of single sensor is using for measurements along of whole profile for each sounding (Bergman, 1978, Larsen at al., 1978, Alduchov, 1985). So, usually reported "standard observational errors" make an actual sense mostly for horizontal/time direction, not for vertical direction.

From the previous considerations the following deductions follows:

1) For detailed profiles (like GPS soundings) the observed upper-air parameters should be reported with accuracy at least 100 times better that in current practice (up to 0.001 °C for temperature, 0.001% for relative humidity and so on). Even it does not add the real accuracy (in the sense of horizontal/time observational errors) for the reported absolute values, but it will

allow getting much precise gradient profiles (because of high correlated observational errors). We understand that it is most unreal way to solve the problem, because of huge international regularizations of upper-air observations.

2) The smoothing methods should be used by researchers for estimations of any derivatives along of "actually observed" new detailed profiles of upper-air parameters.

More specific recommendations for CE-method for cloud detection on the base of radiosonde observations:

For detecting cloudiness boundaries by the CE-method in atmospheric layer 0-10 km with regular/interpolation cubic spline approximation for temperature and humidity profiles better to use the resolution of 300 -600 meters.

For detecting cloudiness boundaries by the CE-method in atmospheric layer near 0-1.5 km there is possibility to use more detailed profiles (with resolution near some tens of meters) by using smoothing spline approximation for temperature and humidity profiles [see, for example, Bartels et al.,1987].

Results can be used for modeling of atmospheric circulation and cloud modeling.

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