Abstract: In this paper we analyze the influence of ice surface emissivity variation on water vapor retrieval accuracy in Arctic region using AMSU-B channels. The data of ice surface emissivity in Arctic is agree with the result of SEPOR-POLEX campaign, and six types of surfaces including open water, nilas, pancake ice, flat first-year ice, ridged first-year ice, multi-year ice are analyzed respectively. Miao’s method and improved version of Selbach are used to retrieve Integrated Water Vapor (IWV) over each type of surface respectively. Analyzing the IWV retrieved with the two methods mentioned above, several results can be obtained. First, the uncertainty of retrieved IWV results from emissivity variance is calculated over each kind of surface. Second, retrieval algorithms over nilas and pancake need new coefficients independently for their emissivities are relatively larger than that of other surfaces. Third, the IWV retrieved with improved version of Selbach has less average bias but larger variance than that with Miao’s method over five kinds of surfaces except pancake ice.

Key-Words: Integrated Water Vapor, surface emissivity, AMSU-B, passive microwave remote sensing

1 Introduction

Atmospheric water vapor is essential in meteorological and environmental study. Till now, integrated water vapor (IWV) content retrieval can be successfully done over oceans from microwave sensor measurements. However, water vapor retrieval method over land is still being explored for the error of IWV retrieved with existing methods are relative large. The root-mean-square (rms) error of IWV retrieved with AMSRE data and neural network algorithm is about 3.0kg/m$^2$ over European land [1], and that with infrared measurement reaches 6.8kg/m$^2$ over European and African regions [2]. The error of IWV retrieved with GPS measurement varies in different region. While in Antarctic the standard deviation is about 1.0kg/m$^2$ [3], and in European the rms reaches 6.0kg/m$^2$ [2]. Ground-Based millimeter wave radiometry measurement can be used to retrieve IWV in Arctic with uncertainty less than 5% [4], but the application of this method is limited by location.

The polar regions are an important but ill-understood component of the global climate system and understanding water vapor over these regions are significant. Miao’s method was proposed in 1997 to retrieve the low amount IWV using SSM/T2 channels over the ice covered polar regions [5][6]. This method has been proved to be very effective in both Arctic and Antarctic region by subsequent studies [7][8][9][10]. Comparing to the relative large error of IWV retrieved with GPS measurements, Miao’s method only induce mean bias -0.08kg/m$^2$ and standard deviation 0.79kg/m$^2$ with AMSU-B data in Antarctic [3].

Although Miao’s method can only retrieve IWV less than 6.0kg/m$^2$ with AMSU-B channels combinations [6][11], the value is generally satisfied within the cold and dry Antarctic plateau area [6]. Wang improved the water vapor retrieval accuracy by introducing 220GHz channel on MIR (Millimeter-Wave Imaging Radiometer) into combination with AMSU-B channels, and he assumed that ice surface emissivity changes linearly with frequency in the range of 150-220GHz [7][8]. Although this method can not apply to current satellite sensors for there is no similar channel combination, the result shows that the difference of emissivities at different channels has influence on the accuracy of IWV retrieval. In order to determine the highly variable emissivity of ice surface, Europe launched the airborne SEPOR-POLEX campaign in March 2001 over Arctic region. Measurement results show a clear linear relationship between the surface emissivities at 157 and 183GHz with a rms of 0.012 [12]. This result has been applied to improve Miao’s method for retrieving IWV with correction scheme.
by Selbach [12]. The improved version of Selbach assumed the emissivities at 150 and 183GHz satisfy linear relationship according to SEPOR-POLEX results [12][13] and reduced the systematic offset of retrieved IWV. However, the rms error of retrieved IWV remains the same or even becomes larger.

Then a question arises, the influence on accuracy of retrieved IWV by ice surface emissivity variance, how large will it be? As there is no data of emissivity at 150GHz, we use the emissivity at 157GHz instead, which is retrieved from SEPOR-POLEX campaign.

Based on the work of Miao [6] and of Selbach [12], we analyze the accuracy of retrieved IWV under two assumptions about the relationship between emissivity at 150 and 183 GHz over six types of surfaces in Arctic region, including: open water, nilas, pancake ice, flat first-year ice, ridged first-year ice, multi-year ice. For the first assumption, we consider the emissivity at 150 and 183 GHz are equal to each other, which is adopted by Miao [6]. Then Miao’s method is applied to retrieve IWV over each kind of ice surface. For the second assumption, it is assumed that the emissivity at 150 and 183GHz satisfy linear relationship, which is adopted by Selbach [12]. Improved version of Selbach is applied to retrieve IWV over each kind of ice surface too. At last, average bias and standard deviation of retrieved IWV against radiosonde IWV with the two assumptions are calculated and analyzed respectively.

2 Study Area and Material
In the process mentioned above, our researches focus on Arctic region, and 3000 radiosonde profiles recorded in this area are selected from IGRA [14] database within the time range 1991-2007. The water vapor burden in each profile is less than 6.0kg/m² with 50 profiles in every 0.1kg/m² interval. Fig.1 shows the locations of stations for these profiles. Then, we simulate the brightness temperature of AMSU-B channels with VDISORT and truncate the upper levels of the data leaving 30 levels of each profile in calculation. The numerical characteristic of Arctic surfaces emissivities origin from SEPOR-POLEX [12][13], which include mean and standard deviation at 157 and 183GHz over six kinds of ice surfaces as shown in Fig.2. In the process of simulating brightness temperature of AMSU-B channels, equivalent surfaces emissivities data are generated according to their numerical characteristics.

3 Methodology
The influence of ice surface emissivity variation on the IWV retrieval accuracy is analyzed in following procedure. First, twelve groups of equivalent emissivities at 150 and 183GHz of all kinds of surfaces are generated according to the mean values and standard deviations of 157 and 183GHz, which origin from SEPOR-POLEX campaign. Second, the emissivities in each group and all profiles are inputted into VDISORT to calculate brightness temperatures of all AMSU-B channels. Third, so-called “focal point” position and new coefficients are drawn with Miao’s method [6] and improved version of Selbach [12] respectively. At last, the results of IWV retrieved with these two new algorithms are analyzed and compared over every kind of surface. All the process is done under two schemes: assuming the emissivities at 150 and
Fig. 3: Retrieved IWV obtained from Miao’s method [6] vs radiosonde IWV over six kinds of surfaces: open water, nilas, pancake, flat first-year ice, ridged first-year ice, multi-year ice. Every point and short line is corresponding to one profile used for retrieval.

183GHz are equal to each other or satisfy linear relationship.

3.1 Scheme 1: Assume $\varepsilon_s$ Equal

Assuming the emissivities at 150 and 183GHz are equal to each other, we take the emissivity data at 183GHz as the base and retrieve IWV with the new “focal point” and coefficients created according to Miao’s method [6]. The selected 3000 profiles are divided into two groups: 1500 profiles are used to draw new coefficients and “focal point” position in the algorithm; the other 1500 profiles are used to verify error of retrieved IWV against radiosonde IWV. The biases and standard deviations of retrieved IWV corresponding to every profile are shown in Fig. 3.

3.2 Scheme 2: Assume $\varepsilon_s$ Linear

Assuming the emissivity at 150 and 183GHz satisfy linear relationship of

$$\varepsilon_{s150} = 1.12 \varepsilon_{s183} - 0.1111$$

(1)

Equivalent emissivities at 150 and 183GHz are needed to generate firstly in this process. When the IWV is less than 1.5kg/m² and only three channels centered at the strong water vapor absorption line at 183GHz will be used, we generate the equivalent emissivities at 183GHz as same as in the first scheme. But, when the retrieved IWV become larger than 1.5kg/m², the 150GHz channel has to be taken into combination. The emissivities at 183GHz are generated as a base, and then the corresponding data at 150GHz are generated with the limitation of satisfying the equation (1) and the rms between $\varepsilon_{s150}$ and $\varepsilon_{s183}$ is 0.012 [12]. The same 3000 profiles are used as the first scheme, and the new coefficients and “focal point” position drawn according to improved version of Selbach are used in the new

Assuming the emissivity at 150 and 183GHz satisfy linear relationship of
retrieval algorithm [12]. The biases and standard deviations of retrieved IWV corresponding to every profile are shown in Fig.4.

4 Discussion
The average bias and average standard deviation of retrieved IWV with Miao’s method [6] and with improved version of Selbach [12] are compared over all kinds of ice surfaces as shown in Fig.5. We can see in this figure that the improved version of Selbach get less bias but larger standard deviation than those with Miao’s method over five kinds of surfaces except pancake. The results obtained from these two methods show that over all six kinds of surfaces, the average bias of retrieved IWV with two methods are both less than 0.5kg/m², and the average bias even less than 0.1kg/m² over open water, flat first-year ice, ridged first-year ice and multi-year ice.

Over open water, the influence of its surface emissivity variation on retrieved IWV accuracy is much less than its average bias. Over nilas and pancake, average bias and average standard deviation of retrieved IWV with both of methods are relatively larger than that over other surfaces and there is saturation when the IWV is less than 6.0kg/m² (shown in Fig.3 and Fig.4). The reason for these phenomena is that emissivity of nilas and pancake is very high, but the coefficients and “focal point” position in retrieve algorithms are drawn with all six types of surfaces emissivity. If we use these unsuitable coefficients and “focal point” position to retrieve IWV over the two types of ice surfaces, large bias and saturation at a lower IWV burden will be caused, as shown Fig.6. In this figure, point A and B represent IWV are 6.0kg/m² and 4.0 kg/m² respectively, however, if the unsuitable coefficients and “focal point” F are used in retrieve algorithms over high emissivity surfaces, the retrieved IWV of A and B are equal to each other. We can deduce if new coefficients and new “focal points” position of retrieval algorithm are drawn with emissivity features of nilas and pancake, the bias of retrieved IWV will become smaller. Over flat first-year ice, ridged first-year ice and multi-year ice, the average standard deviation is equal or even larger than average bias. That’s mean the main influence of retrieved IWV accuracy is come from the emissivity variance of the three kinds of ice surfaces.

5 Conclusions
We analyzed the IWV retrieve performances over six kinds of surfaces with the two methods and drawn a series of conclusions. First, the uncertainty of retrieved IWV result from emissivity variance is much less than the bias from algorithm itself over open water. Second, retrieval algorithms over nilas and pancake need to draw new coefficients and new “focal point” F are used in retrieve algorithms over high emissivity surfaces, the retrieved IWV of A and B are equal to each other. We can deduce if new coefficients and new “focal points” position of retrieval algorithm are drawn with emissivity features of nilas and pancake, the bias of retrieved IWV will become smaller. Over flat first-year ice, ridged first-year ice and multi-year ice, the average standard deviation is equal or even larger than average bias. That’s mean the main influence of retrieved IWV accuracy is come from the emissivity variance of the three kinds of ice surfaces.
variation of emissivity is the main influence factor to the accuracy of retrieved IWV over these ice surfaces, although the average bias and average standard deviation are both small.

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References:


