Optimal Use of High Resolution Infrared Sounder Channels in Atmospheric Profile Retrieval

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ABSTRACT

Due to correlations among high resolution infrared sounder radiances and retrieval computation efficiency, it is prudent to use a set of statistically less correlated channels which not only retains the majority of measurement information but also yields the most accurate atmospheric profile retrievals. The statistical procedure of these channels selection is described in the paper. The use of optimal selected channels simulated for the measurements of AIRS (Atmospheric InfRared Sounder) in the statistical / physical retrieval is discussed. Simulated AIRS inversion results demonstrate the advantages of using optimal channel set that produce the accurate and stable retrieval solution.

Key words: Stepwise regression, AIRS, Retrieval

I. INTRODUCTION

The high resolution infrared sounder such as AIRS, Interferometric Measurements of Greenhouse gases (IMG), Improved Atmospheric Sounding Interferometer (IASI), Michelson Interferometer for Passive Atmospheric Sounding (MIPAS) etc. are developed for flying on future satellite or polar orbiting platform to replace the current low spectral resolution TIROS Operational Vertical Sounder (TOVS) (Smith et al., 1979). Each one of these instruments will measure thousands of channels within one Field of View (FOV). It has been shown from simulated studies and airborne experiments that the atmospheric profile (T, T_s, H_2O, O_3 etc.) can be achieved with much improved vertical resolution and accuracy from these high spectral resolution infrared sounder observations. However, a practical application of these advanced measurements requires an efficient retrieval method to inverse these large volume of radiance data in a timely fashion. Both linear and nonlinear physical retrieval methods have been established and developed for atmospheric profile retrieval from infrared sounder observations (Zeng, 1974; Smith et al., 1985; Susskind et al., 1984; Eyre 1989; Li et al., 1994). Since the inversion problem is ill-posed and there are radiance correlations among high spectral resolution infrared channels, it is critical to use a set of optimal channels in physical retrieval procedure which is statistically less correlative to obtain a final stable solution. In this paper, a stepwise regression procedure was applied to AIRS calculated radiance data from TOVS Initial Guess Retrieval (TIGR) data set for channel selection. The statistical / physical retrievals from AIRS simulated data by use of these selected channels show that an optimal use of channels can stabilize the retrieval procedure thus improve the

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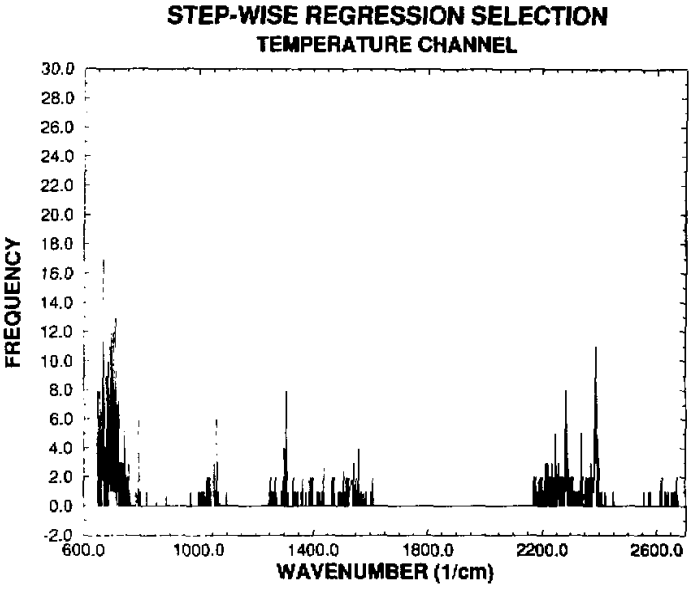

Fig. 1 Selected channels for temperature retrieval from 2372 AIRS channels.

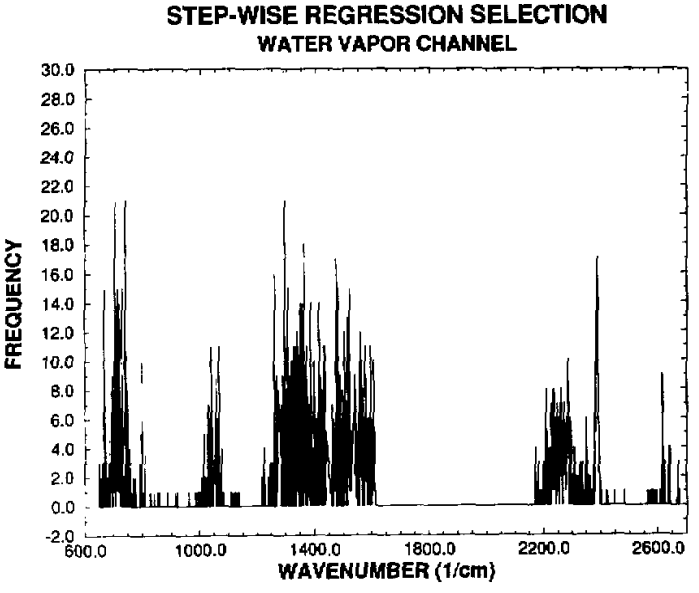

Fig. 2. Selected channels for water vapor retrieval from 2372 AIRS channels.

accuracy of solution.

II. STEPWISE REGRESSION PROCEDURE FOR CHANNEL SELECTION

In this paper the TIGR 1761 atmospheric profiles are used as dependent samples, the

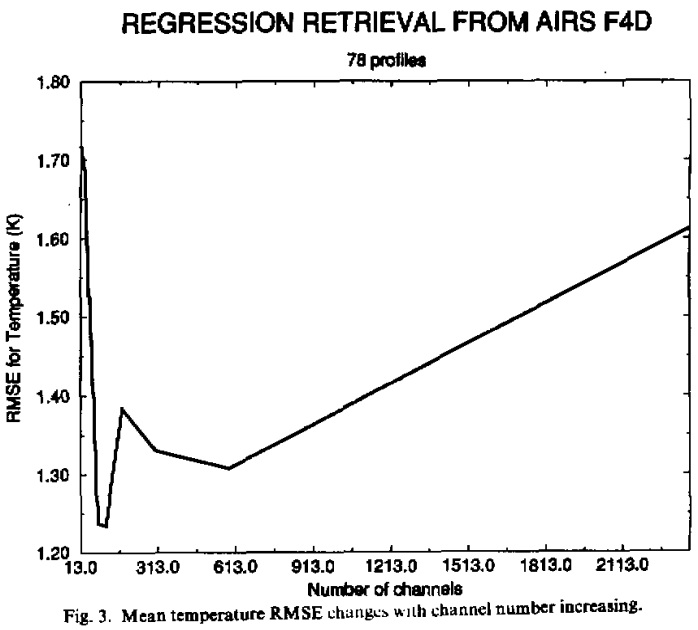

Fig. 3. Mean temperature RMSE changes with channel number increasing.

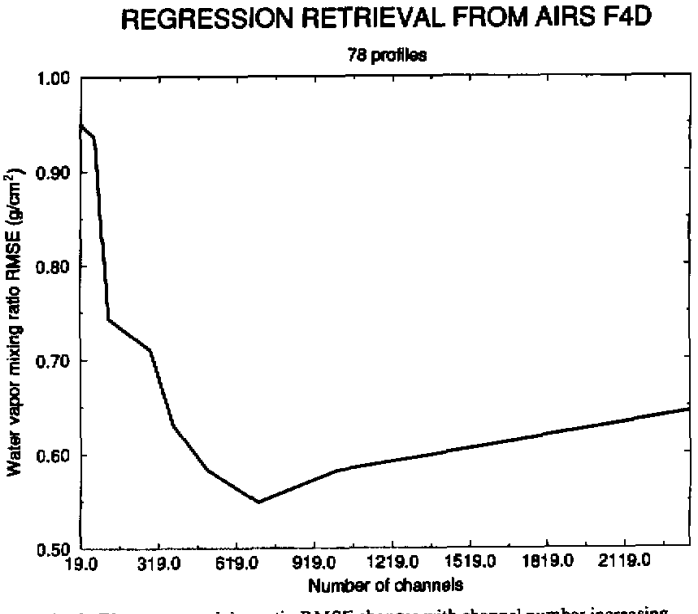

Fig. 4. Water vapor mixing ratio RMSE changes with channel number increasing.

AIRS radiances are calculated from TIGR through RTE model.

Assuming that $X = (x_1, x_2, \cdots, x_n)$ is a profile which is a vector of atmospheric temperature profile, water vapor mixing ratio profile and surface skin temperature, $y_j = R(X)$,

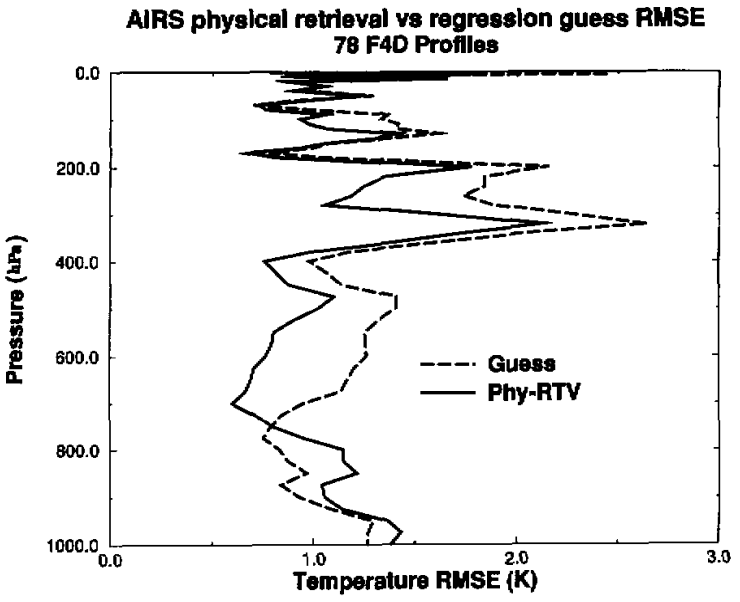

Fig. 5. Physical retrieval temperature RMSE.

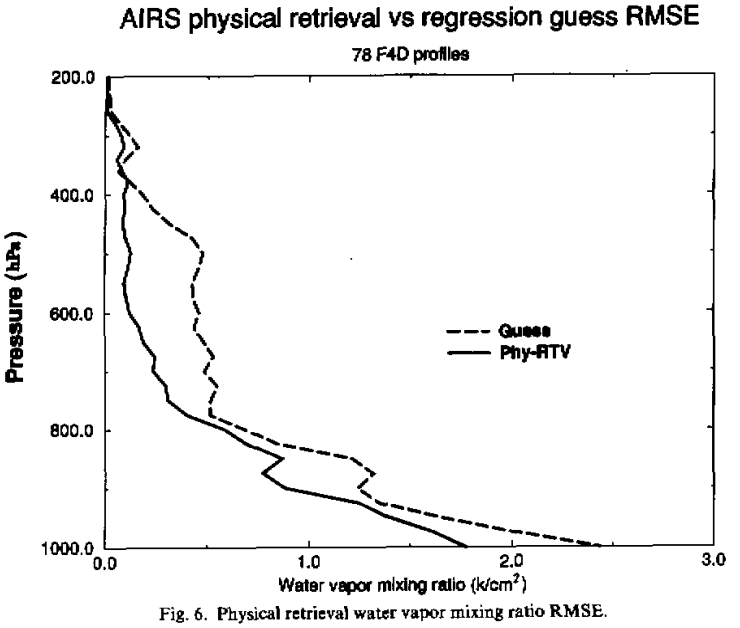

Fig. 6. Physical retrieval water vapor mixing ratio RMSE.

$j = 1, 2, \cdots, K$ is the calculated radiance. K is the total number of channels. Then for $x_i (i = 1, 2, \cdots, n)$ we use stepwise regression procedure to obtain a set of n_i channels S_i, $\bigcup_i S_i$ is the set of total selected channels, each of selected channel has an index which numerates the fre-

quency used in whole stepwise regression procedure. Fig. 1 shows the selected channels for temperature retrieval from 2372 AIRS channels using stepwise regression, the X axis is the AIRS 2372 channels in wavenumber, the Y axis is the corresponding frequency of using that channel in the stepwise regression procedure. Fig. 2 is selected channels for water vapor retrieval from 2372 AIRS channels. It can be seen that 587 channels are selected for temperature retrieval, and 1007 channels are selected for water vapor retrieval. Since there are many temperature channels among the selected water vapor channels, total 1150 channels from 2372 AIRS channels are selected for atmospheric profile retrieval.

III. OPTIMAL USE OF SELECTED CHANNELS IN STATISTICAL ATMOSPHERIC PROFILE RETRIEVAL

The satellite sounding data contain the global atmospheric profile information, with current used operational low resolution HIRS data, only low vertical resolution atmospheric structure can be retrieved. With increasing the infrared spectral resolution, the improved vertical resolution and accurate atmospheric profile can be deduced. On the other hand, it may be impossible to improve the high vertical resolution and retrieval accuracy of atmospheric profile infinitely by infinitely adding too more channels in retrieval procedure.

Let us illustrate this problem by applying least square regression procedure to AIRS simulated data set F4D with different channel subsets which are obtained by using different frequency threshold cuts. For example, those channels with frequency in stepwise regression for temperature are greater than 1 form a channel subset of 306 channels for temperature retrieval. Table 1 lists the different channel subsets from 2372 AIRS channels. Fig. 3 is the F4D 78 retrieval temperature profiles mean Root Mean Square Error (RMSE) (1.0 hPa–1000 hPa) changes with the increase of channel number. Fig. 4 denotes water vapor mixing ratio RMSE (300 hPa–1000 hPa) change with different channel number. Results show that with the increase of channel number both temperature and water vapor results become better, but with too more channels in statistical retrieval, the temperature and water vapor results will not be better again, even get worse. This means there are optimal channels in statistical retrieval. In this study 587 channels for temperature retrieval and 1007 channels for water vapor mixing ratio retrieval selected from 2372 AIRS channels in total are suitable for temperature and water vapor retrieval respectively. Optimal use of channels can also be illustrated in simultaneous non-linear physical retrieval experiments described in next section.

Table 1. Different Channel Subsets from Stepwise Selected Channels

K (use freq.> K)	Channels for TEM	Channels for WV
0	587	1007
1	306	705
2	172	506
3	111	377
4	81	286
5	60	224
6	43	172
7	29	129
8	17	98
9	13	70
10	8	54

IV. SIMULTANEOUS NON-LINEAR PHYSICAL RETRIEVAL OF ATMOSPHERIC PROFILE BY OPTIMAL USE OF CHANNELS

The non-linear simultaneous physical retrieval methodology has been developed for

TOVS operational application and AIRS simulation study (Li et al., 1994). In this study, regression retrieval using statistically selected optimal channels was used as first guess in the non-linear simultaneous physical retrieval with 3 different channel sets: 522, 1150 and 2372 channels, the first channel subset is composed by those channels whose temperature use frequency (Fig. 1) is greater than 1 or water vapor use frequency is greater than 3 (Fig. 3), the second channel subset is selected from stepwise regression procedure as described in Section II. Table 2 shows the first guess and retrieval RMSE (K) of temperature and the first guess and retrieval RMSE (g / kg) of water vapor mixing ratio from the 3 different set of channels. It can be seen that there is no obvious temperature accuracy improvement with full use of all channels used. For water vapor retrieval, there is a significant improvement by use of statistically optimal channels than by use of a small channel subset, but the accuracy of retrieval becomes much worse when all 2373 channels are used. This reflects the impact of channels selection in water vapor retrieval.

Table 2. Physical Retrieval RMSE from Three Different Sets of Channels

No. of Ch.	T-guess	W-guess	T-retrieval	W-retrieval
522	1.308	0.4544	1.096	0.3504
1150	1.308	0.4544	1.090	0.2922
2372	1.308	0.4544	1.036	0.4156

V. CONCLUSION REMARKS

Following conclusions can be drawn from the simulated study above.

(1) The high spectral resolution infrared sounder data have the capability to improve the retrieval accuracy of atmospheric profile.

(2) A set of statistically optimal channels selected from stepwise regression procedure is suitable for retrieval, adding too more channels will have no improvement to retrieval accuracy.

(3) The non-linear simultaneous physical retrieval can improve the regression based first guess much, this is significant for future satellite data application.

(4) These preliminary results are obtained from statistics, physical concern about optimal use of channels witll be carried out at CIMSS / UW in the near future.

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