CrIS channel selectin for the KMA-UM data assimilation based on an iterative method

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1 Introduction

The Cross-track Infrared Sounder (CrIS) on the S-NPP satellite lunched in October 2011 consists of 1305 channels on three bands in the normal mode. For the efficient CrIS data dissemination, Gambarcorta and Barnet (2013) proposed 399 selected channels to alleviate problems related to transmission, storage and data processing while preserving full channel capability. 134 channels (operational set) among them are currently used for the data assimilation (DA) in the KMA-UM model, and these channels represent temperature, humidity and surface. However, it may not be considered optimal for the DA because 399 channel set are mainly selected to preserve the information as much as resolved by all CrIS channels.

Therefore, in this study we suggest a set of new channels relevant for KMA-UM DA system with an linear iterative method introduced by Rodgers (1996) and evaluate through ideal 1D-VAR experiment. The results indicate that the new channel set leads to improved RMSE of overall temperature and humidity fields.

2 Data & Methodology

Cross-track Infrared Sounder (CrIS)

The CrIS sensor on the S-NPP consists of the three bands in LWIR (9.14-15.38㎛), MWIR (5.71-8.26㎛) and SWIR (3.92-4.64㎛), 1305 channels in normal mode. At one single scan, 30 FORs observe the earth radiance and one single FOR is composed of 9 FOVs arrange 3 x 3 array.

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Band	Channel #	Range (cm^{-1})	Resolution (cm^{-1})
LWIR	713	650 – 1095	0.625
MWIR	433	1210 – 1750	1.25
SWIR	159	2155 – 2550	2.5

Atmosphere profile data set

The atmospheric scenario used here is ECMWF 83P 101L (Matricardi et al, 2008) composed of 83 vertical profile set for T, H_2O, O_3, CO_2, CO, CH_4 and N_2O at 101 levels. Data set is for the purpose of generating RTTOV coefficient. Thus it ensures the representativeness of atmospheric constituents.

KMA-UM background error covariance (B)

Since 2016, KMA has been operating the UM global model(UMN768L70) which improves dynamic core and raises model resolution from 25 km to 17 km. In this study, optimal channel set is based on the operational KMA-UM background error covariance (30S – 30N).

This matrix consists of 43 levels (1013 hPa to 0.1 hPa) for temperature and 26 levels (1013 hPa to 113 hPa) for water vapor (figure 1).

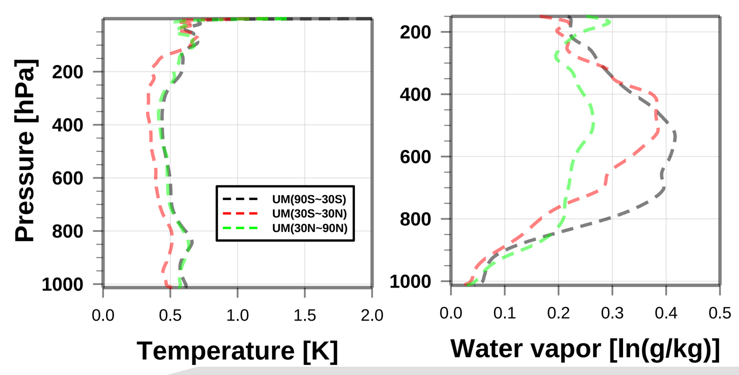


Fig 1. Standard deviation of temperature and water vapor from operational KMA-UM Background error covariance.

CrIS observation error covariance (R)

The observation errors are assumed as unbiased Gaussian and as being uncorrelated between channels. Thus, only diagonal component in R matrix is employed to channel selection (figure 2). In order to configure the same environment as operation system, one error covariance is used for all profile data set and there is no scene correction.

CrIS instrument noise performance has been stable and consistent in the each band section for 9 FOVs, and also the effect of noise correlation is negligible on the overall CrIS NEdN (Zavyalov et al., 2013).

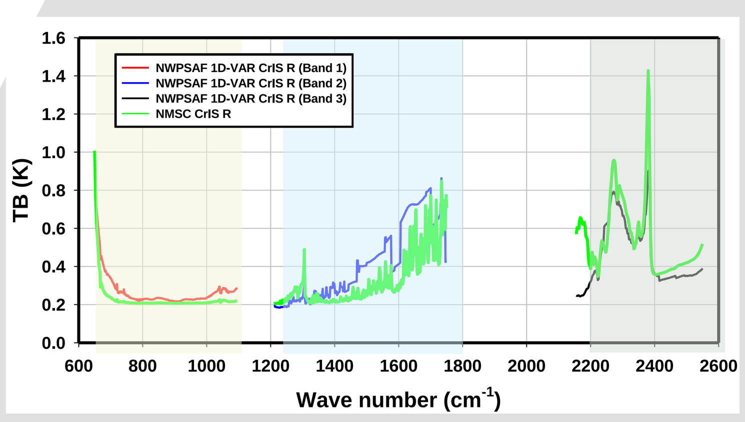


Fig 2. Total observation errors estimated from instrument error, forward model error and trace gases error.

Channel classification

To classify the channel of interest, we employ the method by Gambacorta and Barnet (2013) called as spectral purity. The variation between unperturbed and perturbed atmospheric states are computed by RTTOV-11, and these differences indicate the channel of interest.

Here, the channels influenced by CH_4, CO and NO_2 (these gases are mainly affected the infrared range), and Non-LTE are classified to remove the selection process, and the channels of interest as CO_2, O_3 to focus on (Figure 3).

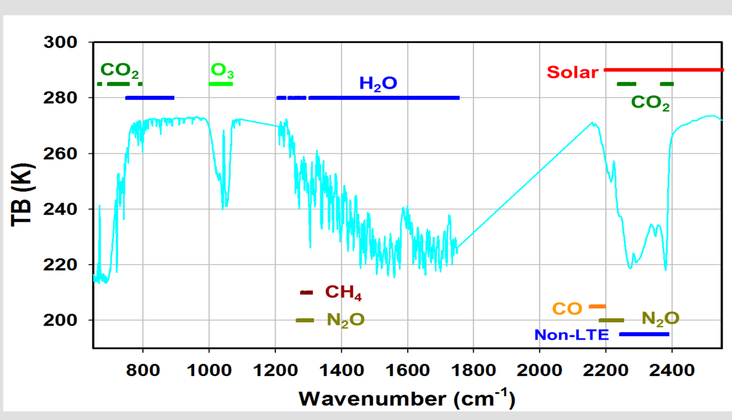


Fig 3. The channel distribution of interest from sensitivity analysis

Methodology of channel evaluation

The iterative method proposed by Rodgers (1996) uses the degree of freedom for signal (DFS) to evaluates the impact of all each single channel. For the linear or weakly nonlinear case, the analysis error covariance can be expressed as eq (1) for singular channel. h is a Jacobian normalized to the single channel observation error.

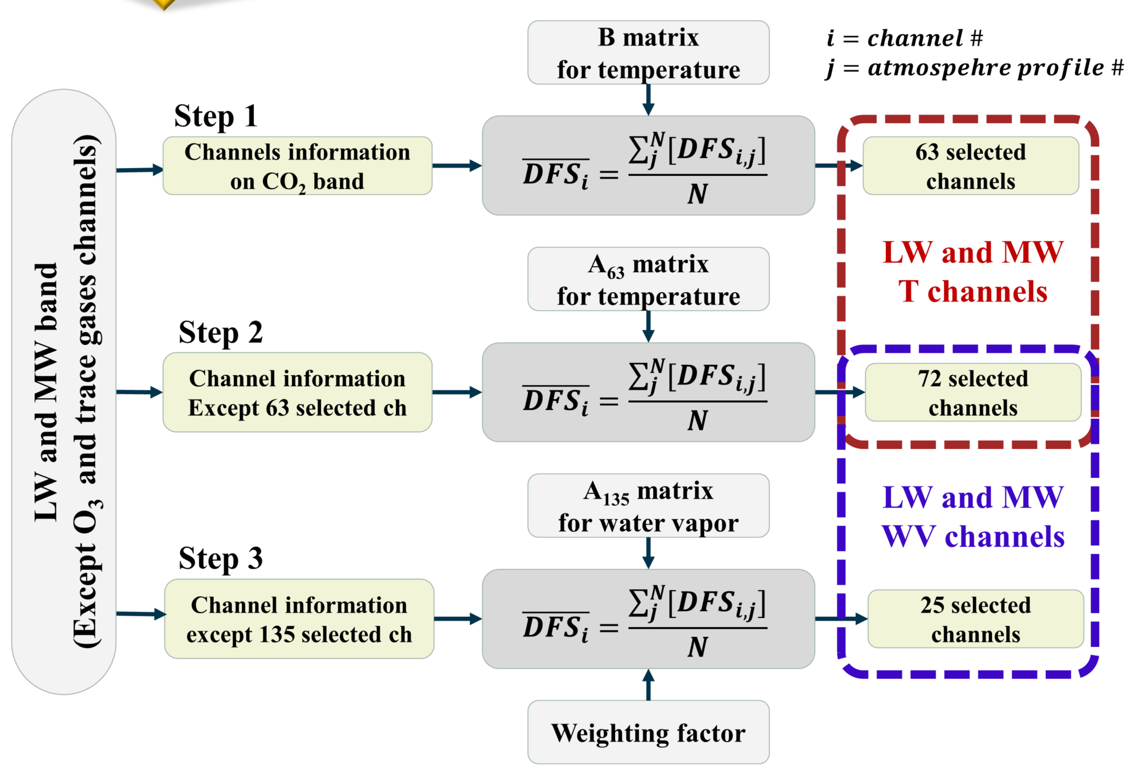
$$A_i = A_{i-1}\left[I - \frac{1}{(1+Bh)^T h} h(Bh)^T\right] \qquad (1)$$

Starting from A_0=B, A_i is computed for all single channel. Here, A_{i-1} is upgraded by the information taken by all previous selected channels. DFS is quantitative index that evaluates the improvement reflected in the information from normalized channel Jacobian as given in eq (2).

$$\text{DFS} = Trace(I - A_i A_{i-1}{}^{-1}) \qquad (2)$$

The channel with the highest improvement evaluated by DFS is selected. And, it is repeatedly performed until the requirement is satisfied.

3 Channel selection



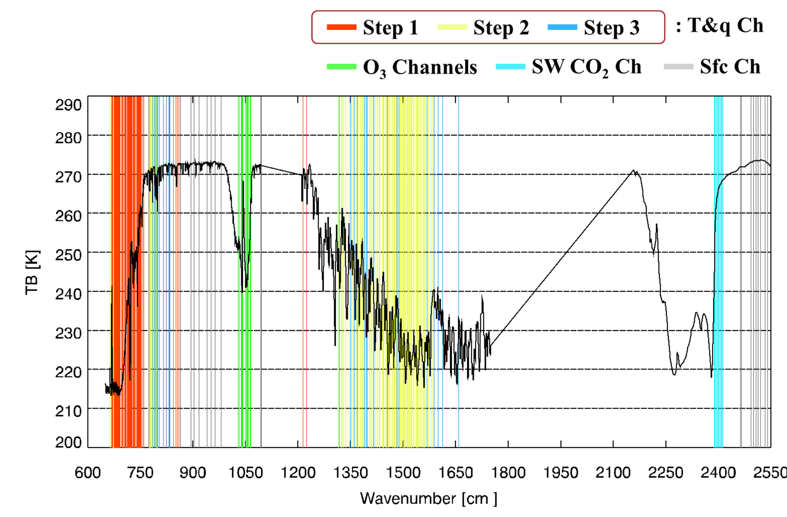


Fig 4. Spectral distribution of the 208 CrIS Channels

➔ To ignore the correlation due to apodization, the adjacent channel of the selected channel is excluded (Collard, 2007).

➔ Step 1: The evaluation of the channels on CO_2 band for temperature B matrix was perform first.

➔ Step 2: For the remaining channels on LW and MW band except O_3 band were further evaluated for temperature B matrix. When performing an evaluation against all channels, the temperature information clearly comes from CO_2 channels, but also apparently comes from the water vapor channels. And also, the reason for evaluating the channels by separating the temperature and water vapor background error is that it is difficult to evaluate the DFS value of two parameters in the same criteria.

➔ Step 3: The contribution of water vapor to DFS around upper troposphere is comparatively large despite small amounts (Noh et al, 2017). Here, we apply weighting factor to normalized Jacobian to alleviate the contribution of the upper-troposphere in channel selection process (figure 5).

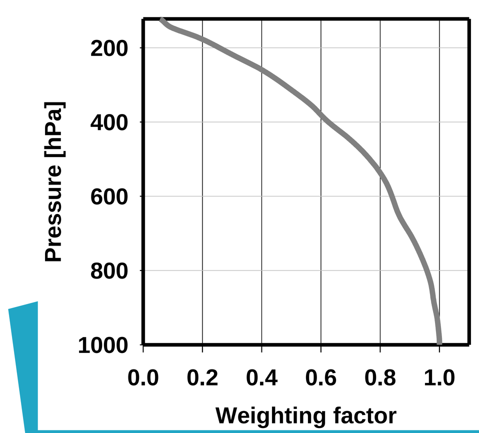


Fig 5. Vertical structure of Weighting

➔ Among the 1011 available channels, 160 temperature and humidity channels on LW and MW band were selected. About 16% of the total volume can account for approximately 65 % of total DFS of 1011 Channels.

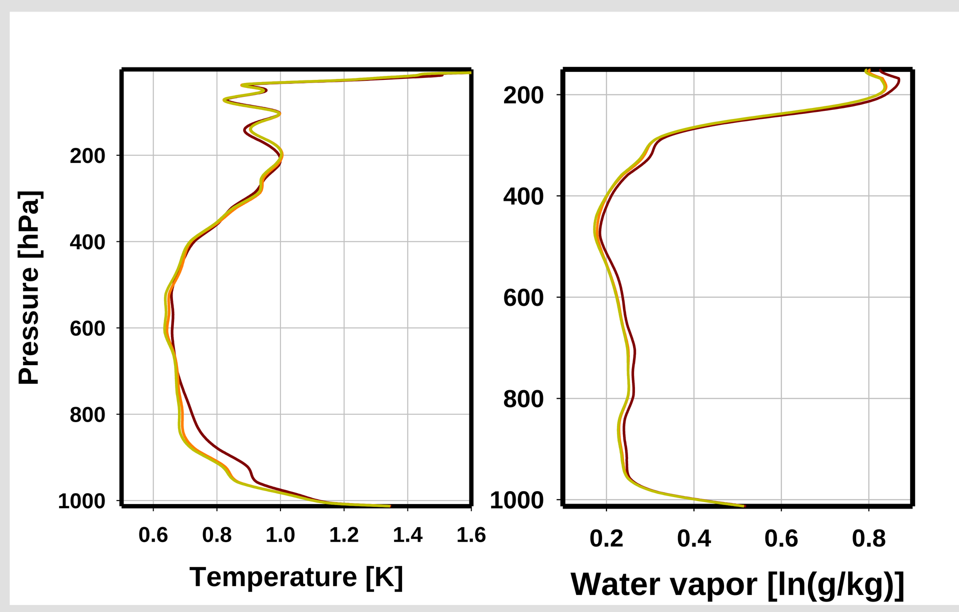
➔ Step 4, 5: O_3 channels and Solar channels were evaluated in the same as step 1.

➔ For surface channels, 22 window channels proposed by Gambarcorta and Barnet (2013) are taken.

4 Experiment & Conclusion

Experiment 1: When different Background error covariance were used in the same method, 70% of the channels were common. A similar result is also shown in Collard (2007).

Experiment 2: Ideal 1D-Var experiment for independent background error covariance.



Independent profile set: 1000 profiles

- Current UM CrIS Channel Set (# 134) T & q: 121 Ch, sfc: 13 Ch
- New CrIS Channel Set (# 147) T & q: 135 Ch, sfc: 12 Ch (Step 1 + Step 2)
- New CrIS Channel Set (# 171) T & q: 160 Ch, sfc: 11 Ch (Step 1 + Step 2 + Step 3)

➔ The new set provides more information in lower troposphere against current UM CrIS channel set.

➔ It is reasonable to decide the number of channels by considering the appropriate ratio between the channels and the information provided.

➔ After selecting more than a hundred channels, it would be more efficient to manually supplement the channels based on the research or the model performance (Collard 2007, Collard and McNally 2009)

➔ We are planning to select the channels using non-linear method by Noh et al (2017) and to compare the channel set of linear method.

5 Reference

Collard, A. D., 2007: Selection of IASI channels for use in numerical weather prediction. Q. J. R. Meteorol. Soc., 133, 1977–1991.

Collard, A. D. and A. P. McNally, 2009: The assimilation of Infrared Atmospheric Sounding Interferometer radiances at ECMWF. *Q. J. R. Meteorol. Soc.*, 135, 1044–1058.

Gambacorta, A., and C. D. Barnet, 2013: Methodology and information content of the NOAA NESDIS operational channel selection for the cross-track infrared sounder (CrIS), *IEEE Trans. Geosci. Remote Sens.*, 51(6), 3207–3216.

Noh, Y. C., B. J. Sohn, Y. J. Kim, S. W. Joo, W. Bell and R. Saunders. 2017: A new Infrared Atmospheric Sounding Interferometer channel selection and assessment of its impact on Met Office NWP forecasts. *Advances in Atmospheric Sciences*, *34*(11), 1265-1281.

Rabier, F., N. Fourrie, D. Chafai, and P. Prunet, 2002: Channel selection methods for infrared atmospheric sounding interferometer radiances. *Q. J. R. Meteorol. Soc.*, 128, 1011–1027.

Rodgers, C. D., 1996: Information content and optimisation of high spectral resolution measurements. pp 136–147, in: Optical spectroscopic Techniques and Instrumentation for Atmospheric and Space Research II, SPIE 2380, Hays PB, Wang J (eds).

Zavyalov, V., M. Esplin, D. Scott, B. Esplin, G. Bingham, E. Hoffman, C. Lietzke, J. Predina, R. Frain, L. Suwinski, Y. Han, C. Major, B. Graham, and L. Phillips, 2013: Noise performance of the CrIS instrument. J. Geophys. Res., 118, 108–118.

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