Geostationary hyperspectral infrared sounder channel selection for capturing fast-changing atmospheric information

Di Di, Jun Li, Han Wei and Ruoying Yin

Corresponding : didi@nuist.edu.cn

School of Atmospheric Physics, Nanjing University of Information Science & Technology, Nanjing, China

Abstract

An alternative channel selection method is developed through adding an M index which reflects the Jacobian variance over time; the adjusted algorithm is ideal for the Geosynchronous Interferometric Infrared Sounder (GIIRS) which is the first high spectral resolution advanced IR sounder onboard a geostationary weather satellite. Comparisons between the conventional algorithm (information entropy iterative method) and the adjusted algorithm show that the channels selected from GIIRS by the adjusted algorithm will have larger brightness temperature diurnal variations and better information content than the conventional algorithm, based on the same background error covariance matrix, the observational error covariance matrix, and the channel blacklist. The adjusted algorithm is able to select the channels for monitoring atmospheric temporal variation while retaining the information content from the conventional method. The one-dimensional variational (1Dvar) retrieval experiment also verifies the superiority of this adjusted algorithm; it indicates that using the channel selected by the adjusted algorithm could enhance the water vapor profile retrieval accuracy, especially for the lower and middle troposphere atmosphere.

Method

Conventional: information entropy iterative

$$A = (H^T R^{-1} H + B^{-1})^{-1} \qquad A_i = A_{i-1}\left[I - \frac{h_i (A_{i-1} h_i)^T}{1 + (A_{i-1} h_i)^T h_i}\right]$$

The conventional channel selection algorithm, based on information content of the measurements, reflecting the reduction in the analysis error A over background B could be could be quantified by a degree of freedom for signals (DFS) or the entropy reduction (ER).

$$\mathrm{DFS} = \mathrm{tr}(I - AB^{-1}) \qquad \mathrm{ER} = -\frac{1}{2} ln(AB^{-1})$$

Adjusted: conventional + M index

$$\mathrm{M} = \min(l_1, l_2)\sqrt{\frac{\sum_{i=1}^{\min(l_1,l_2)} (J_{2,i} - J_{1,i})^2}{\sum_{i=1}^{\min(l_1,l_2)} J_{1,i}^{\ 2}}}$$

The adjusted algorithm combines the conventional algorithm with the channel M index. The adjusted algorithm combines the conventional algorithm with the channel M index. It aims to select the channels that maximize the information gain on the background atmospheric state and also contains the greatest sensitivity to atmospheric state variability.

Result 1- channel blacklist

The main purpose of the pre-screening stage is to avoid channels with larger forward model uncertainty, including channels that have (1) trace gas absorption whose variability is not well depicted in the radiative transfer model; (2) larger simulation errors or uncertainties among various radiative transfer models; and (3) higher Jacobian nonlinearity or multiple Jacobian peaks.

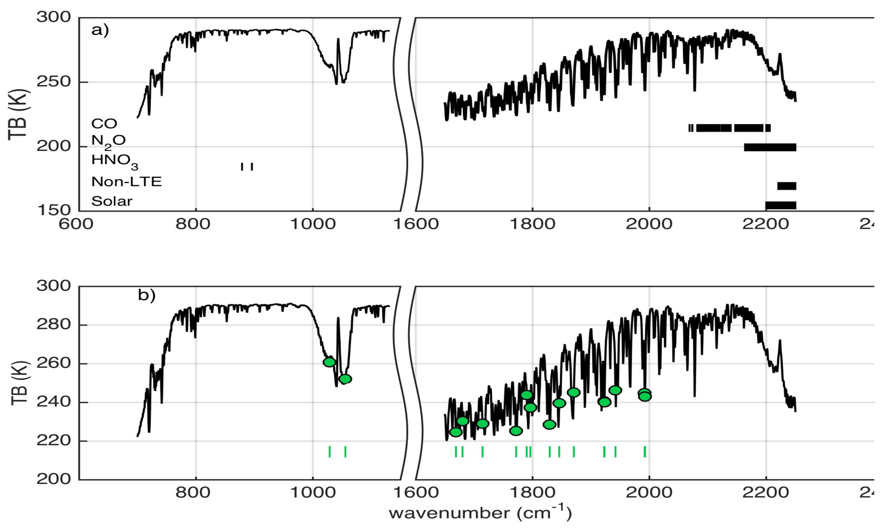

Fig 1. Blacklisted channels that have a) trace gas absorption such as CO, N_2O, HNO_3, or impacts from solar irradiance and non-LTE (marked with solid line); and b) larger model BT simulation errors (marked with green circle).

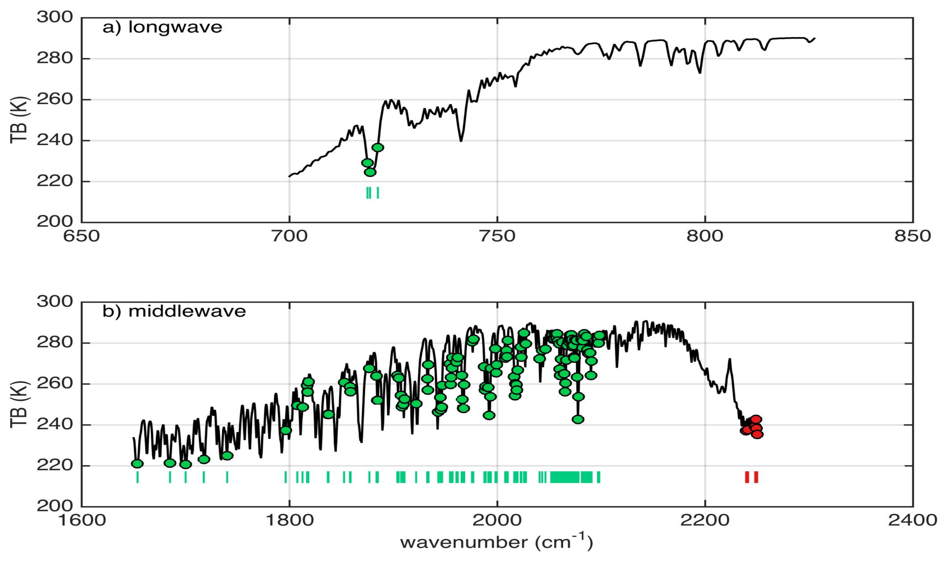

Fig 2. Channel blacklist for those channels that have higher nonlinearity or multiple peaks in Jacobians. Green represents channels blacklisted due to multiple peaks and red represents channels blacklisted due to higher nonlinearity.

Result 2– channel selection

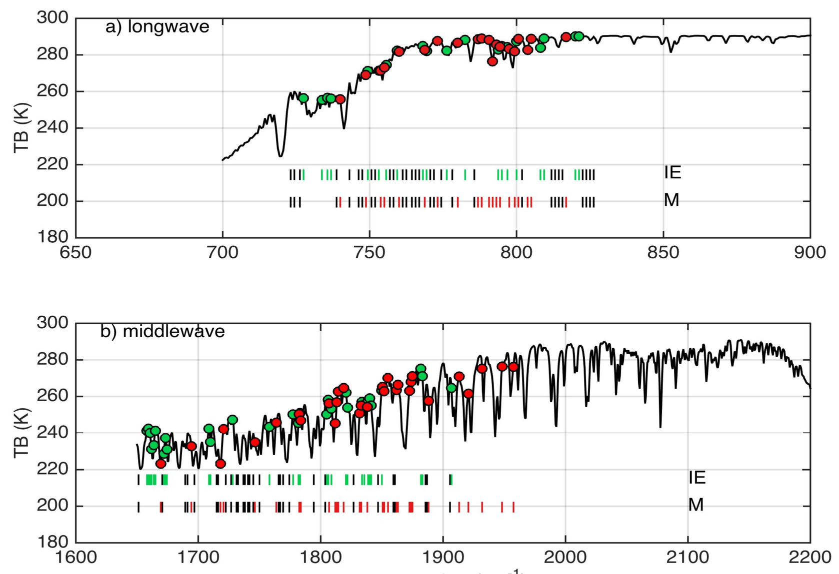

Fig 3. The spectral locations for 50 temperature and 60 water vapor channels selected by a) the conventional algorithm and b) the adjusted algorithm, respectively.

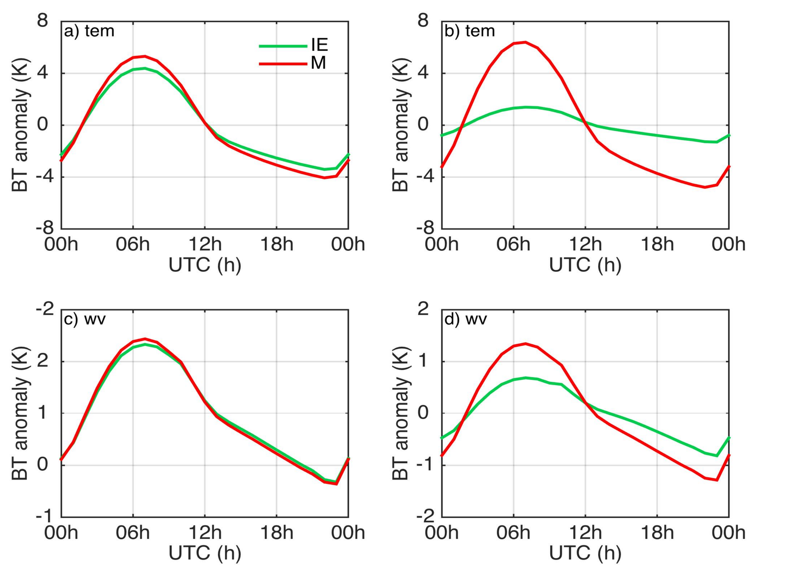

Fig 4. Diurnal variations in BT anomalies of a) temperature and c) water vapor distinct channels, in which BTs are averaged in area and in channels. The results are calculated from 67 profiles. The same results for b) temperature and d) water vapor distinct channels but based on one of the 67 profiles. The green solid lines and the red solid lines represent the results from the conventional algorithm and the adjusted algorithm, respectively.

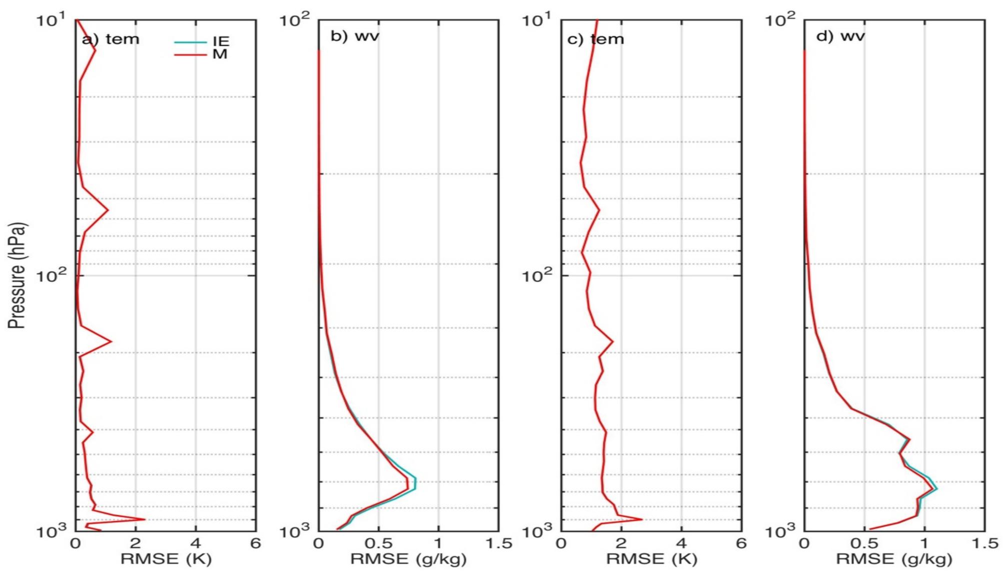

Fig 5. a) Temperature and b) water vapor retrieval root-mean-square-error (RMSE) for two sets of constant channels selected by the two algorithms, using the original hourly ERA5 reanalysis dataset as the test profiles. Similar results for c) temperature and d) water vapor retrieval RMSE but using the hourly-averaged ERA5 reanalysis dataset as the test profiles.

conclusion

- Based on the same background error covariance matrix, the observational error covariance matrix, and the channel blacklist, the channels selected by the adjusted algorithm will have larger BT diurnal variations and much closer information content than the conventional algorithm. It means that the adjusted algorithm could improve the ability to select the best channels for monitoring atmospheric temporal variation while retaining the information content from the conventional algorithm.
- 1DVAR experiments indicate that using the channel selected by the adjusted algorithm could enhance the water vapor profile retrieval accuracy, especially for the lower and middle troposphere atmosphere.