

Estimating the Retrievalability of Temperature Profile from Satellite Infrared Measurements

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Introduction

Radiance measurements of satellite infrared radiometers are used widely to retrieve atmospheric temperature and moisture profiles. The retrieval precision was restricted by two major factors: (1) radiance observation error; (2) vertical resolution. The poor vertical resolution is ascribed, in part, to the low spectral resolution. So the retrieval precision from satellite data are limited in fact. We use the limits of retrievalability as a measure of utmost precision or potential for retrieval. It is analogous with the limits of predictability in NWP.

Now a new method is developed to estimate the retrievalability of atmospheric temperature profiles based on EOF technique and generalized linear inverses theory (GLIT). EOF technique is used to extract the vertical structure of the atmosphere and GLIT is used to separate the atmospheric modes that can be retrieved from satellite data. Utilizing the method, the change of the atmospheric temperature structure can be expressed with the first several EOF, and then the distribution character of the error can be directly estimated according to the radiative transfer equation (RTE).

Method of estimating retrievalability

The linearized RTE can be expressed in a matrix increment form: $\delta T_p = K \delta T$. Based on the theory of 'singular vector decomposition (SVD)', K can be decomposed by effective parameter subspace V_p and effective data subspace U_p . Then define retrievalability as:

$$r_T = \langle \delta T, V_p \rangle / \sqrt{\langle \delta T, \delta T \rangle} = 1 - \sigma_{r,k} / \sigma_{T,k}$$

where $\sigma_{T,k} = \sqrt{\langle \delta T, \delta T \rangle}$; $\sigma_{r,k} = \sqrt{\sigma_{rd,k}^2 + \sigma_{s,k}^2 + \sigma_{e,k}^2}$ is the total retrieval error containing the error caused by observation, the resolution error, and truncation error of EOF.

(1) The variance of retrieval error caused by observation error can be expressed as:

$$\sigma_{rd}^2 = \frac{\langle \varepsilon_{rd}^T \varepsilon_{rd} \rangle}{M} = \frac{tr(\varepsilon_{rd} \varepsilon_{rd}^T)}{M} = \frac{\sigma_d^2}{M} tr(V_p \Lambda_p^2 V_p^T) = R \sigma_d^2$$

where $tr(A)$ is the trace of matrix, σ_d^2 is the variance of observation errors.

(2) Solve the eigenvalue problem of a sample matrix A with elements $\delta T_{i,j}$ by EOF: $A^T A q_i = q_i^T x_i$, then δT_i can be expanded according to the orthogonal primary function:

$$\delta T_i = \sum_{i=1}^{M'} c_{ii} q_i + \varepsilon_E$$

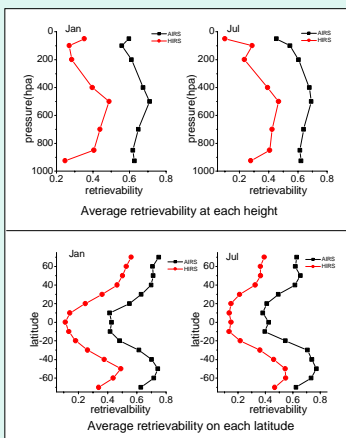
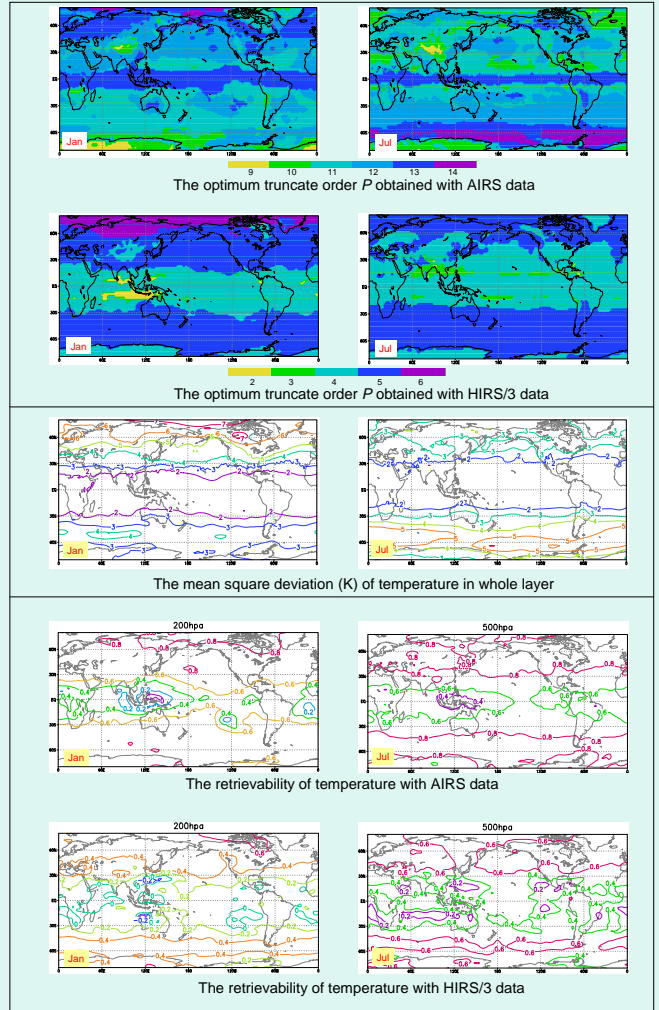
where ε_E is truncation error. Project primary function q_i to subspace V_p , then the error variance of resolution at level k can be solved as:

$$\sigma_{s,i,k}^2 = \langle \varepsilon_{i,i,k}^2 \rangle = \langle c_i^2 \rangle e_{i,k}^2 = \langle c_i^2 \rangle (q_i - \sum_{j=1}^p a_{ij} v_j)^2$$

(3) The truncation error of EOF can be expressed as: $\sigma_{e,k}^2 = \langle \varepsilon_{E,k}^2 \rangle$

Data illustration

Utilize NCEP re-analysis data with $1^\circ \times 1^\circ$ resolution in January and July from 1999 to 2003 as the atmosphere parameter samples and the simulative brightness-temperature of AIRS, HIRS/3 as observations. First, confirm the optimum truncate order which corresponding to the least error of the whole layer; then count the globe retrievalability in January and July.



Summary and discussion

(1) The optimum truncation order decides the effective information offered by satellite measurements. The results show that the optimum truncation order is small in low latitude regions and high in mid-high latitude areas. This character relates to the rage of temporal fluctuation of the atmospheric temperature.

(2) The retrievalability of temperature is low at upper and lower atmosphere; high between 400hpa and 850hpa. For geography distribution, the retrievabilities are low in the low latitude marine regions and some regions in Antarctica; relatively high in mid-high latitude and mainland regions. This is consistent with the distribution of optimum truncation order and partly represents the relationship between retrievalability and temperature fluctuation.

(3) Comparing the retrievalability obtained with AIRS and HIRS/3 data, the former is higher 0.15-0.4 than the latter and the retrievalability with the AIRS data are improved more evidently in low latitude regions. It implies that using AIRS data can improve the temperature retrieval in theory. Especially using AIRS data, the average retrievalability at middle atmosphere near 500hpa in mid-high latitude regions can reach 0.8.