Robust Variational Inversion: with simulated ATOVS radiances

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Methodology

In remote-sensing retrieval and data assimilation, one generally minimizes a cost function to obtain the best state estimate. For our robust variational inversion algorithm, the cost function can be written as

$$J(x) = \frac{1}{2} \left( x - x_b \right)^T W(r) \left( x - x_b \right) + \frac{1}{2} \left( H(x) - y \right)^T R(x) \left( H(x) - y \right)$$

where $x$, $x_b$ are respectively the background and observation error covariance matrices. $x, y$ are respectively the background and observation vectors. $H$ is the observation operator which transforms from $x$ to $y$ space. $W(r) = \begin{cases} \frac{1}{2} & \text{if } |r| < \sigma_0 \\sigma_0^2 & \text{otherwise} \end{cases}$, with $\sigma_0$ and $\sigma$ the threshold values.

Weight function $W(r)$ is a diagonal weight matrix with the elements $w(ri)$ and the normalized departure $r_i = (y_i - H_i(x))/\sigma_i$. $w(ri)$ is the cost function of observation term. Obviously, for the square cost function $F(x) = x^2$, $w(x) = 1$.

For non-square cost functions which can be derived from Maximum-Likelihood Principal, $w(x)$ will not be 1 any more. A descent algorithm generally requires to compute the gradient of the cost function at each iteration, namely

$$\nabla f(x) - B'(x - x_b) + B'[W(r) R^{-1}(H(x) - y)] = 0$$

Note that the weight matrix $W(r)$ should be recomputed with the updated residual $r$ at each iteration, so the algorithm is also called “re-weighted Least-square” method.

A Robust 1DVAR Inversion framework

For testing the above algorithm, a Robust 1DVAR Inversion system originated from the 1DVAR code of ECMWF (Chevallier et al, 2002) is implemented to apply to the ATOVS radiances retrieval problem. A few new developments of the original code were done for this study: (1) the RTM interface is updated from RTTOV6 to RTTOV7; (2) the analysis variables are changed from the original 3 cloud variables profile to the free-cloud temperature $T$ and the specific humidity $q$ profile; (3) adding the robust weight function interface.

For observations, we take ATOVS HIRS channels 6,7,8,10,11,12 (sensitive to humidity), AMSU-A channels 3-18 (sensitive to temperature) and AMSU-B channels 3-5 (humidity channels). The observation error covariance matrix $R$ is supposed to be diagonal, and equal to the diagonal elements of $BB^T$ which is explicitly computed using K matrix model of RTTOV. That is, the weight of the background and observations is considered to be equal. The error standard deviation of different channels is shown in Fig. 2. We can see that the error of humidity channels is much larger than that of temperature channels as also shown by Andersson et al. (2000).

Fig. 1: The background error standard deviation for $T$ and $q$ (left panel) and the error correlation for $q$ (right panel). The temperature error values are taken from Eyre et al. (1993), and the specific humidity error follows the scheme of Rabier et al. (1998). The error correlation is the same for $T$ and $q$ beside that the error correlation of $q$ above 100hPa is removed.

Fig. 2: Specified observation error standard deviation for chosen ATOVS channels. They are obtained by explicitly computing $BB^T$.

Summary

- A robust 1DVAR framework is implemented for retrieval of $(T, q)$ profile from ATOVS radiances.
- Preliminary test of robust algorithm with Huber weight function indicates potential of the method.
- Further study in detail is need to compare with other weight function and to apply to real data.

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References


