THE DEVELOPMENT OF AN INTERACTIVE RETRIEVAL/ANALYSIS FORECAST ALGORITHM

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1. INTRODUCTION

A new retrieval system for deriving temperature and moisture profiles from TIROS-N Operational Vertical Sounder (TOVS) measurements has been developed. This system, unlike the current operational library search approach, uses the six-hour forecast from the National Meteorological Center's (NMC) Medium Range Forecast Model for constructing the retrieval algorithm's initial (first) guess. The system is interactive because the satellite-retrieved parameters, in addition to conventional in situ data, are analyzed to produce initial conditions for the subsequent forecast by NMC's Global Data Assimilation System (GDAS), and that forecast is used as the first guess for the subsequent temperature/moisture retrievals. The system is expected to become operational as part of NMC's GDAS in 1993.

The realization of the importance of the satellite retrieval problem to numerical weather prediction (NWP) resulted in the convening of a U.S. government Interagency Satellite Retrieval Workshop in July 1989 which included satellite retrieval and NWP experts from the National Aeronautical Space Administration (NASA) and the National Oceanic and Atmospheric Administration (NOAA). The Workshop participants agreed that an advanced satellite retrieval system for numerical weather forecasting should be developed as soon as possible. This system should take advantage of the best components of the operational system at NOAA's National Environmental Satellite Data and Information Service (NESDIS) and those from the experimental approaches at NESDIS and at NASA. There was a general agreement among the Workshop participants that the various sophisticated inversion methods (e.g., the NESDIS operational system (Fleming, et al., 1986b, 1988); the NASA research scheme (Susskind, et al., 1984)) should have about the same accuracy, given the same radiances. It was decided that the largest enhancements to the retrievals would result from changes to the cloud clearing algorithm and improvements to the first guess in the inversion procedure. There was a strong consensus among the Workshop participants, that, over most of the globe, the present-day accuracy of the model 6 hour forecast during the data assimilation should provide a very good first guess to the retrieval process.
2. RETRIEVAL ALGORITHM

The retrieval algorithm is based on the NESDIS operational system, which uses the minimum variance solution, to simultaneously solve for atmospheric temperature, skin temperature and water vapor mixing ratio. The retrieval algorithm can be expressed by the following equation:

$$ V = V_{fg} + S A^T (S A^T + N)^{-1} (R_{obs} - R_{fg}) $$

where $V$ is the solution vector containing atmospheric temperature/moisture and skin temperature, $V_{fg}$ is the solution's first guess vector, $R_{obs}$ is the observed radiance vector, where each element represents a different channel measurement, $R_{fg}$ is the radiance first guess vector, $S$ is the solution covariance matrix, $A$ is the radiative transfer matrix, and $N$ is the noise covariance matrix.

The main difference between the NESDIS operational algorithm and the interactive retrieval algorithm is the manner in which the vectors and matrices in the above equation are computed. In the NESDIS operational system, $S$ and $A$ are computed from a priori information corresponding to the retrieval's geographic zone. There are a total of 27 geographic zones based on latitude, surface type (ocean/land) and night/day. The solution and radiance first guesses are obtained by searching through a historical library of collocated radiance and radiosonde observations (Goldberg et al., 1988). The 10 library radiance vectors that are most similar to the observed radiance vector are averaged to produce $R_{fg}$, and the 10 collocated radiosonde observations are averaged to produce $V_{fg}$. In the interactive retrieval system, there is a single $A$ matrix, computed from a global ensemble of departures between the radiosonde and the 6-hour forecast. The $A$ matrix is computed from the $V_{fg}$, which is now the 6-hour forecast. $R_{fg}$ is computed from $V_{fg}$ where $R_{fg} = AV_{fg}$. Since $R_{fg}$ in the interactive retrieval system is computed from radiative transfer, an adjustment is applied to remove the systematic bias commonly observed between measured and computed radiances due to uncertainties in radiative transfer physics as well as in radiance calibration, and other factors. This is a very important adjustment, since a systematic bias in the first guess synthesized radiance manifests itself as a systematic bias in the retrieved solution vector. Fig. 1 shows an example of differences between observed and uncorrected calculated brightness temperatures for HIRS channel 7 of TOVS as a function of latitude. The increase of scatter and bowing in the tropics could be due to a number of reasons including uncertainties in the radiative transfer of its handling of moisture and/or uncertainties in the moisture. Nevertheless, the scatter is reduced and more uniform after the computed radiances are adjusted (Fig. 2). A description of the bias correction procedure can be found in Fleming et al., 1991.

Note that in the NESDIS operational system, $A$ is not computed from $V_{fg}$ because it would require considerable computer processing time to perform the nearly 100,000 retrievals that are computed daily. In the interactive
Fig. 1  Observed and uncorrected computed brightness temperature differences for HIRS channel 7 as a function of latitude.

Fig. 2  Observed and bias adjusted computed brightness temperature differences for HIRS channel 7 as a function of latitude.
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retrieval system, we are using NMC's high speed Cray computer, which does not impose any such constraints.

Another important feature of the interactive retrieval system is that Eq. (1) is solved directly at the NMC model sigma levels. The capability to retrieve temperature and moisture at the NMC model levels has the double advantage of eliminating: 1) the error due to vertical interpolation of the model 6 hour forecast to the levels where the retrievals are produced (previously, constant pressure levels), and, 2) the error due to vertical interpolation in the objective analysis step of the NMC global data assimilation system with the new NMC spectral statistical interpolation scheme (Parrish and Derber, 1992, Derber et al., 1991).

3. PARALLEL ASSIMILATION TEST RESULTS

Several tests have been conducted using the NMC global data assimilation system in parallel with the operational system, and have confirmed that: 1) retrieval accuracy is significantly improved, compared to that of the NESDIS operational system, with the use of a 6 hour forecast as the retrieval initial guess, and, 2) 5-day forecasts are significantly improved in the Southern Hemisphere. The medium-range (day 5) anomaly correlation statistics for the southern hemisphere extratropics (20° - 80°) are shown in Fig. 3. These results were from an 11-day test at a model resolution of T126 (~105 km at the Equator) for the time period May 23, 1992 to June 2, 1992. In the conventional data rich northern hemisphere, the forecasts are comparable using either interactive or operational retrievals (see Fig. 4).

Several enhancements to the system can be expected after the initial implementation of the interactive retrieval system. These enhancements include improvements in water vapor retrievals and cloud clearing.

4. REFERENCES


Fig. 3  Anomaly correlation scores for 5 day forecasts at T126 resolution over the southern hemisphere (20° - 80°), May 23 - June 2, 1992.

Fig. 4  Anomaly correlation scores for 5 day forecasts at T126 resolution over the northern hemisphere (20° - 80°), May 23 - June 2, 1992.
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