JOINT NESDIS/NASA/NMC EFFORT TO DEVELOP AN ADVANCED SATELLITE RETRIEVAL SYSTEM

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1. INTRODUCTION

The accuracy of operational numerical weather forecasts has steadily increased through the 1980's to the point where it is becoming difficult to routinely expect operational satellite temperature soundings to have a positive impact on the forecasts over the Northern Hemisphere. The realization of the importance of the satellite retrieval problem to numerical weather prediction (NWP) culminated in the convening of a U.S. government Interagency Satellite Retrieval Workshop in July 1989 which included satellite retrieval and NWP experts from NASA and NOAA. The Workshop participants agreed that an advanced satellite retrieval system for numerical weather forecasting and climate monitoring should be developed as soon as possible. This system should take advantage of the best components of the operational system at NESDIS and those from the experimental approaches at NESDIS and at NASA. 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 be beneficial to the retrieval process. The approach of producing and using the satellite soundings "interactively" then naturally follows, where the assimilation model forecast is used as a first guess by the retrieval scheme (Baker et al., 1984). The model forecast has also been used with a variational approach to analyze radiances directly for numerical weather prediction (e.g., Eyre and Lorenc, 1989). The resulting retrievals are then analyzed in conjunction with other available data to produce initial conditions for the subsequent forecast by the assimilating model. Such an approach developed and used extensively in a research model by J. Susskind and collaborators at the NASA Goddard Space Flight Center, has been shown to have a beneficial effect on both the accuracy of the 6 hour assimilation model forecast and that of the retrievals. More importantly, the negative impacts on medium range forecasts over the Northern Hemisphere are, for the most part, eliminated (Susskind and Pfaendtner, 1989). In addition to temperature profiles and precipitable water estimates, a wide range of geophysical parameters (e.g., land and sea surface temperature, ice and snow extent, cloud top pressure and amount, and estimates of outgoing long wave radiation, soil moisture, total ozone, and precipitation) can be produced. A particularly strong point with the interactive approach is that the above parameters are

obtained in a way which is consistent with the mass and wind fields in the assimilation because the 6 hour forecast from the assimilation is used as the first guess for the retrievals. Therefore, not only is an accurate, self-consistent set of data produced for numerical weather forecasting, a powerful climate monitoring system is also created.

2. PROPOSED STRATEGY

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. There was also a strong consensus that the most accurate first guess possible should be used for the inversion problem. Over most areas of the globe that is most likely a forecast provided by a general circulation model during the data assimilation. In areas where the model forecast might be poor as determined by comparing observed (satellite) and computed (model) radiances from the forward problem, a classification approach (i.e., McMillin, 1986b) blended with the model first guess, seems promising.

The Workshop participants strongly agreed that the most important remaining weakness (assuming the use of a forecast first guess) in the NESDIS operational system was in the approach used for cloud-clearing, where an angle correction (to nadir) is performed before cloud-clearing, and, hence, the angle correction procedure must also simultaneously account for clouds. All the participants agreed that the most accurate off-nadir retrievals are produced if the off-nadir radiances are cloud-cleared at the same angle that the satellite views the atmosphere (as in the NASA scheme). In addition, the NASA scheme also uses the forecast temperature information in the cloud-clearing, while the NESDIS scheme does not use this information. On the other hand, a limitation identified in the NASA retrieval scheme was in not utilizing the SSU data for the stratospheric sounding problem, as is done in the NESDIS system.

Various aspects of the NESDIS and GLA retrieval schemes will be intercompared and tested. Retrievals from a combined system will be evaluated using collocated radiosondes, and by conducting forecast impact tests with the NMC global data assimilation system (GDAS). The period May 15, 1988 to July 15, 1988 was selected for use in testing the individual components. Additional forecast impact tests will then be conducted in parallel to the operational system in real time with the combined retrieval scheme.

With the above considerations in mind, the Workshop participants recommended the following steps in order to combine the strengths of the different approaches:

1. NESDIS and NASA will exchange retrieval software.

2. Both retrieval systems will be implemented on the NMC CRAY YMP for experimentation.

3. The NASA approach for cloud-clearing (producing cloud-cleared radiances at the angles of observation) will be tested by NESDIS (but without iteration as in the NASA system).

4. NASA will provide NESDIS cloud-cleared radiances; NESDIS will produce retrievals; NMC will evaluate the analysis/forecast impact.

5. NASA will conduct tests to determine the sensitivity of its cloud-clearing scheme to the number of iterations. Cloud-cleared radiances computed from the first guess, after one iteration, and after the full adjustment made in the NASA system will be provided to NESDIS for comparison.

6. NESDIS will implement their bias correction (on observed radiances during the forward problem) in the NASA code. This will be compared with the NASA approach.

7. Other aspects of the retrieval problem will also be evaluated, such as the ability to retain an accurate first guess and improve a poor one.

The above work has also served as a pilot effort for a recently initiated joint NESDIS/NASA/NMC project to develop an advanced retrieval system. The initial thrusts of this project involve: 1) exporting the NASA approach for cloud-clearing to NESDIS for evaluation, and, 2) developing the capability to combine an air-mass classification guess with the NMC 6 hour forecast guess in regions where the forward calculation differences are large.

3. NESDIS/NMC PILOT STUDY

A joint NESDIS/NMC pilot effort was initiated in early 1989 to develop an interactive retrieval system. Recent results confirm that: 1) the retrieval accuracy is significantly improved, compared to that of the operational system, with the use of a 6 hour forecast as the retrieval first guess, and, 2) the accuracy of the 6 hour forecast is exceeded by the retrieval accuracy using the interactive approach.

Phase II of the pilot effort is now underway which involves developing the capability to retrieve temperature and specific humidity at the NMC model levels. This has the double advantage of eliminating 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 the error due to vertical interpolation in the objective analysis step of the NMC global data assimilation system when the new NMC spectral statistical interpolation scheme (Parrish and Derber, 1991) is implemented in the near future.

Once the retrieval code has been ported to the NMC CRAY YMP, parallel analysis/forecast experiments will be conducted with possible implementation in late 1991 for NMC's internal NWP use. Wider distribution over the GTS will await further discussions with the external users of NESDIS sounding products. Enhancements to the pilot system, as discussed above (e.g., the hybrid model first guess - classification approach, use of the NASA cloud clearing, etc.,), will be implemented following successful parallel analysis/forecast experiments on the NMC CRAY YMP.

4. CONCLUDING REMARKS

The development of an advanced retrieval system, which takes advantage of the best components of the operational system at NESDIS and those from experimental approaches at NESDIS and at NASA, is now underway. This approach should significantly improve the use of satellite data for NWP and for climate monitoring as well.

5. ACKNOWLEDGMENTS

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