ASSIMILTION OF DOD SENSOR DATA INTO OPERATIONAL FORECAST MODELS PE 0602435 (NRL BE-035-02-32)

Nancy L. Baker
Naval Research Laboratory
Monterey, CA 93943-5502
Ph (408) 656-4779, (408) 656-4769 (FAX)
baker@nrlmry.navy.mil

LONG-TERM GOALS:

Remotely-sensed observations from satellites hold great promise for providing a wealth of high-temporal and spatial resolution data, particularly over the oceans. However, it has been very difficult for numerical weather prediction systems to show consistent, positive forecast improvement attributable to satellite retrievals obtained in the conventional manner. By developing techniques for the direct assimilation of the satellite measured radiances, this project will lay the foundation for improved three- and four-dimensional data assimilation systems for global and mesoscale applications. These systems may be run at operational central-site forecast centers or run on-scene to provide operational mission support.

OBJECTIVES:

The objective of this task is to develop variational data assimilation techniques for improving the impact of satellite data on numerical weather prediction systems. Variational techniques provide a means to utilize values that are not directly reflected by the traditional forecast model parameters. In the case of satellite data, variational methods allow for the direct use of the measured radiances, rather than the derived temperature and moisture soundings. Satellite radiances are a challenge to use correctly, and there are many quality control (QC) issues that are unique to each satellite sensor. Efforts at NRL will concentrate on the DMSP microwave sensors, since non-DoD research efforts are focusing on the civilian sensors. Optimal use of these rich data sources should reduce the errors in the analyses that provide initial conditions for forecast models and tactical decision aids, as well as provide valuable information to the forecasters in the field.

APPROACH:

The use of remotely sensed observations is hampered by several fundamental limitations. First, the quantity measured is usually not the quantity needed by the forecast model. Second, there is typically not a one-to-one relationship between what is observed and the derived value. For the example of satellite temperature soundings, the radiance measured in a given spectral channel is emitted from a broad vertical region of the atmosphere rather than a specific pressure level. Consequently, the inverse or retrieval problem becomes formally ill-posed, and essentially an infinite number of temperature profiles are possible from a given set of radiance measurements. In order to constrain the solution, prior information must be specified. For temperature and moisture soundings, the final solution is strongly dependent upon the prior information , and is highly nonlinear for moisture.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 1997**	2. REPORT TYPE	3. DATES COVERED **00-00-1997 to 00-00-1997**

4. TITLE AND SUBTITLE **Assimilation of DOD Sensor Data into Operational Forecast Models PE 0602435 (NRL BE-035-02-32)**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Research Laboratory,Monterey,CA,93943-5502**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**4**	

To reduce the errors introduced by the retrieval process, it is possible to use variational assimilation methods, which are soundly based on optimal nonlinear estimation theory, to assimilate the radiances directly. Proper use of the radiances in this manner is a difficult problem requiring knowledge of remote sensing and data assimilation methods. This approach requires an accurate forward radiative transfer model appropriate for microwave instruments, extensive data quality control techniques for the radiance measurements, and accurate specification of the error characteristics of the observations and background that are used to constrain the guess (including error correlations).

With variational algorithms, a penalty function is minimized with respect to control variables which describe the atmospheric state to be analyzed. The penalty function measures the fit of the maximum likelihood estimate of the atmospheric state to the observations and background (a priori) information. This approach requires computation of radiances computed from the forecast model variables using a forward radiative transfer model. The first step in reaching our goal is to develop a one-dimensional variational analysis (1DVAR) to assimilate satellite radiance data. The simpler, one-dimensional approach is ideal for developing the fundamental understanding of the problem. The most important aspects of the problem, such as development and validation of the forward radiative transfer model, quality control, bias correction algorithms and specification of the error covariances, can all be developed in the one-dimensional context, using easily available workstation resources.

The 1DVAR algorithm also produces vertical profiles of temperature and humidity to replace the conventionally produced retrievals. With 1DVAR, the background or a priori information comes from the six-hour forecast from the Navy's operational forecast models. This background typically contains more information about the current state of the atmosphere than the a priori information used to produce conventional retrievals, and thus constrains the ill-posed problem better. Another important component of 1DVAR algorithms and some retrieval methods is the specification of the background error covariance. It is much easier to estimate this error covariance for the forecast model background than it is for first guess derived from averaged collocated rawinsondes or climatology. Finally, 1DVAR improves upon conventional retrievals because of its self-contained, rigorous quality control.

Together with better quality control algorithms, 1DVAR provides near-term deliverables which can be readily included into the current Multivariate Optimum Interpolation (MVOI) analysis. These two deliverables are expected to improve the forecast model in the short term, although most of the improvement is not expected until the full three-dimensional assimilation of radiances is implemented. The 1DVAR will be used as a radiance pre-processor for the three-dimensional variational (3DVAR) analysis that is being developed concurrently at NRL as a replacement for the MVOI.

Variational methods are also being developed to assimilate satellite retrieved parameters (such as SSM/I total column water vapor) that are not directly related to the model state variables. In this example, the link between radiances and the retrieved quantities is weakly nonlinear and not strongly dependent upon the prior information. Therefore, assimilation of the retrieved quantity will be close to optimal.

WORK COMPLETED:

Most of the necessary components for 1DVAR have been completed, including the minimization algorithms, extraction of the background from the model output fields, and validation methods. The civilian infrared sensor TOVS was used as a proxy until data communications problems between FNMOC and NESDIS (National Environmental Satellite Data Information Services) were resolved. Based on 1DVAR analysis of TOVS, it was determined that partial eigenvector decomposition would be the most efficient method to assimilate radiances in 3DVAR; this capability has been added to NRL's developmental 3DVAR system. The ability to analyze integrated retrieved quantities such as DMSP SSM/I or SSM/T-2 total precipitable water has also been added to 3DVAR. Validation methods were developed to allow for verification/comparison of either 1DVAR retrievals or NESDIS operational retrieved soundings. Retrievals may be compared against either the global model forecast, the analysis, or co-located observations such as radiosonde temperature and humidity or SSM/I integrated water vapor. The development of an appropriate forward radiative transfer model for the DMSP instruments in underway. This effort will leverage existing forward models obtained for SSM/T-1 and SSM/T-2 from NESDIS (OPTRAN) and adapt them for DMSP sensors.

RESULTS:

Preliminary results indicate that the microwave DMSP instruments show promise for providing useful information for data assimilation and numerical weather prediction. This is particularly true for cloudy areas over the oceans for the following reasons. The microwave portion of the electromagnetic spectrum used for microwave temperature and humidity profiling is much less affected by clouds than the infrared portion of the spectrum used by the civilian sensor, TOVS. Therefore, we might expect that the microwave DMSP instruments will provide better information in those regions. In addition, the microwave surface emissivity is an important input parameter for microwave remote sensing. Since the variations in surface emissivity over water are small and the emissivity easier to estimate, retrievals over open oceans tend to be of higher quality. Evaluation of retrieved quantities indicate much larger errors over land, ice and snow. We anticipate that rigorous quality control and observation screening algorithms will need to be developed for these sensors.

Variational assimilation methods use a short-term forecast from the NWP model as the background or first guess. It is crucial that the forecast model error correlations of temperature and humidity are correctly specified. Using a method of transforming independent variables, new correlation functions have been derived that are simple to compute yet provide a closer fit to the data than methods currently in use. These new correlation functions led to an improved agreement between 1DVAR retrievals and rawinsondes.

IMPACT:

This research should lead to a meaningful improvement in the quality of the atmospheric analyses and a more consistent performance from the forecast models as a result of the improved assimilation of the abundant satellite information. Improvements in numerical prediction systems translate to improved mission support and cost savings for the Navy.

TRANSITIONS:

The systems being developed are primarily designed to run at a central site like Fleet Numerical Meteorology and Oceanography Center. They are also candidates for other applications such as the on-scene systems being developed by the Navy. The prototype version for TOVS radiance using one-dimensional variational methods to produce retrievals was transitioned to 6.4 and is being tested with the operational NOGAPS system.

RELATED PROJECTS:

PE 0602435N (Data Assimilation and Quality Control for Shipboard Analysis/ Prediction System) and PE 0603207N (Variational Assimilation and Physical Initialization) are closely related projects to develop data assimilation systems for shipboard and central-site use at FNMOC.

REFERENCES:

none