# DATA ASSIMILATION AND ANALYSIS
PE 0602435 (NRL BE-035-02-19)

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## LONG-TERM GOALS:

To build data assimilation systems that analyze all scales of weather, within both central site and on-scene computer environments. This project will deliver a highly effective data assimilation system that will produce the best linear unbiased estimate of the atmosphere's state at a particular time, using a prediction model, observations from a 24 hour period, and the most recent analysis. The ultimate system will take a number of years, yet deliverables will be made on components of this system so that the operational data assimilation system will continue to improve throughout the research period. Near-term deliverables include the newest version of the mesoscale data assimilation system, the one-dimensional variational method to assimilate satellite radiances directly, and the capability to assimilate rain-rates into the global prediction system. The end result will be more precise data assimilation systems, based on sound optimal estimation theory, which will lead to better, longer-term weather forecasts by the various prediction systems. The impact will be greatest in the ocean areas due to improved utilization of satellite and on-scene sensors.

## OBJECTIVES:

To develop a fully modern three-dimensional variational method capable of assimilating measured quantities of non-conventional and remotely sensed observations in addition to the conventional values of temperature, wind, and moisture that are currently processed. To improve methods of computing error characteristics of the various components of the data assimilation suite and the observations, and to develop methods to detect errors in both the data and the prediction system. To design and build systems and support software that use modern local area networks, database technology, and graphics libraries, to better display and diagnose important features of the environment. To exploit research and development at other weather prediction centers and laboratories worldwide. To improve current tropical cyclone intensity and location analyses and predictions by assimilating into forecast models the observed tropical cyclone structure and/or asymmetry, which can be derived by utilization of in situ observations and satellite data. The information needed to enhance the initial analyses as well as the forecast includes cloud top temperatures, the moisture field, the precipitation rate, storm size, the asymmetric gyre, and the past tendency of movement and intensity changes.

## APPROACH:

The first step is to develop the one-dimensional variational (1DVAR) analysis to assimilate satellite radiance data. This analysis will later be extended to a three-dimensional (3DVAR) version that will be applied to all data types. These methods will form the foundation to a four-dimensional variational procedure in future work. These objectives must be achieved both within the computer intensive central-site environment and aboard ship where time, manpower, and computer resources are limited. To address all of the diverse applications, systems are first developed and tested at the central site, then simplified for

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transition to regional centers and the on-scene environment. For central site applications, sophisticated numerical techniques for data quality control, data analysis, and model initialization will be used, whereas for regional and tactical applications, simplifying approximations will be made that consider the data types and analysis issues important to the high-resolution coastal zone. Developments in each task are subject to rigorous demonstration and testing at Fleet Numerical Meteorology and Oceanography Center (FNMOC) and at the NRL TESS(3) laboratory before transition is attempted.

Navy Operational Global Atmospheric Prediction System (NOGAPS) and Coupled Ocean/Atmospheric Mesoscale Prediction System (COAMPS) will be used to test the effects of assimilating in situ and remote observations of tropical cyclone structure and environmental flows. New retrieval methods based on multiple satellite sensors and channels onboard polar orbiting and geostationary platforms will give improved definitions of these parameters. In addition, moisture fields surrounding the tropical cyclones, determined from microwave sensors, can also be utilized to provide better moisture analyses, which are critical for tropical forecasts in general. Furthermore, the assimilation of rainfall rates retrieved by SSM/I, and inferred from OLR and other sensors will be tested. Various methodologies, such as the dynamical initialization, the diabatic initialization (reverse parameterization) and the relaxation (nudging) methods, will be tested to find the best way to assimilate rainfall rates.

**WORK COMPLETED:**

The first version of 3DVAR has been developed with numerous features, including: 1DVAR TIROS Operational Vertical Sounder (TOVS) temperature retrievals, utilization of significant level temperature and winds from radiosondes, direct assimilation of non-standard variables such as vertical integrals of moisture, ozone, and scatterometer wind speeds, specification of error correlations in isentropic coordinates, a vertical coordinate decomposition into covariance model eigenvector space, massively parallel design, new statistically derived covariance functions that guarantee the positive definite requirement, and a new data quality control algorithm for aircraft data. A completely new data processing program has been developed that allows display of the many aspects of the observations, such as departures from the background, missing and rejected data, and fit to the final analysis. This processed information will be archived to improve statistical parameters for the analysis, and to aid in the detection of malfunctioning instruments.

The TOVS forward algorithm has been implemented into an optimal estimation method (1DVAR) and final integration tests are being performed. Much of the 1DVAR effort has been put into developing models of error structure of the various components. The new method of transforming the vertical coordinate onto eigenvector space allows the 3DVAR analysis to utilize the significant and mandatory level information from radiosondes, pibals, satellites, and aircraft without increasing the total running time significantly. The analysis also runs on massively parallel computers, making it very efficient on workstation computers. North America can be analyzed in less than ten minutes on a single processor. The efficiency of the 3DVAR will allow on-scene applications to utilize this method, the best available analysis for three dimensions. The project to assimilate rain rate into the Navy's global prediction system, NOGAPS, has continued with the development of a sophisticated analysis that combines satellite and conventional information into a continuous detailed depiction of rain rates. A data quality control program was developed for the automated aircraft observations of temperature and wind. Tests using this program show the types of errors unique to these instruments are numerous, but detectable and fixable.

**RESULTS:**

Ongoing studies using the NOGAPS global model show that the satellite retrievals obtained in the conventional manner are not very good over the northeast Pacific region, often giving negative effect. These soundings contain contamination from clouds and poor background information. The 1DVAR algorithm, on the other hand, only uses the information provided by the satellite. It does not need to have information from other sources, such as adjacent radiosondes, and it does a much more complete job of data quality control. Evaluation tests of this method are just beginning.

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. A suite of new parameters have been derived using a history file of innovation vectors, and these models are giving slight improvements to NOGAPS forecasts.

The four methods commonly used to reduce pressure to sea level were compared, and a method that insures consistency of temperature under the terrain was found to produce the least distortion in the computed result. Minimizing these errors eliminates error feedback in data assimilation of sea-level pressure observations.

The assimilation of SSM/I rainfall rates has proven beneficial in the track prediction of Typhoon Flo of 1990. The SSM/I retrievals, however, are not always available due to the narrow swath width of the sensor. To fill in the temporal and spatial gaps with no SSM/I flyby, a method has been developed to utilize the infrared (IR) cloud top brightness temperature (BT). The automated algorithm is obtained by comparing the IR BT with SSM/I rainfall rates when a collocated and coincidental SSM/I retrieval is available. The algorithm then can be used until the next SSM/I flyby. The result of the assimilation and forecast experiments indicate that the IR rainfall rates obtained by this method are beneficial, but the improvement is not as significant as from the SSM/I rainfall rates. In an ongoing effort, the impact of water vapor- tracked winds and sounding winds will be evaluated in the prediction of Hurricane Opal using a high resolution limited area model.

Water vapor (WV)-tracked winds are retrieved from subsequent images in the water vapor channel. The water vapor sounding winds are retrieved from multi-channel images to obtain a vertical profile. These winds, located in cloud-free regions where cloud tracked-winds are not available, have proven to be very valuable in predicting tropical cyclone tracks in NOGAPS by improving the analysis of the tropical cyclone in the initial conditions. The retrieved WV-tracjed winds are mostly distributed between 100 to 400 hPa. It is hypothesized that the WV-tracked winds can better define the westerly trough and therefore improve the track and perhaps the intensity prediction.

**IMPACT:**

This research will lead to a significant improvement in the quality of atmospheric analyses and forecasts 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:**

A regional version of the three-dimensional variational data assimilation system was integrated into COAMPS with extensive tests just beginning. The one-dimensional variational method to ingest satellite radiances from TOVS into the assimilation model was implemented for 6.4 testing. The methods to assimilate precipitation rates into the global data assimilation system is being tested using the various precipitation data available from satellite and land stations.

**RELATED PROJECTS:**

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

**REFERENCES:**

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