

TECHNIQUES TO ASSIMILATE SSM/I OBSERVATIONS OF MARINE ATMOSPHERIC STORMS

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LONG TERM GOALS

Our long-term goal is to use DMSP SSM/I satellite data to improve the depiction of marine atmospheric storms, which in turn would aid nowcasting in support of execution of operations at sea and forecasting of the evolution of these storms in support of planning. The anticipated results of our research are algorithms and prototype software to use SSM/I observations of integrated water vapor (IWV) and surface wind speed in data assimilation. These algorithms, based on the work of Hoffman and Grassotti (1996, referred to as HG96 below), are designed to match observable features in the SSM/I data to those in the short term forecast (or background) field used in the data assimilation system, shifting the background field to best match the available satellite data. The algorithms will be optimized for the Navy weather central regional prediction facility models but will be adaptable to other satellite data and other forecast models.

OBJECTIVES

In practical terms, the goal of this project is to translate the work of HG96 into an operational algorithm and to perform sufficient testing to demonstrate the utility of this algorithm by showing that it improves the forecasts of marine storms. To reach this goal we will work towards the following key technical objectives: case selection; impact study; algorithm development and tuning; and parallel run. Suitable cases for study will be selected. For each selected case one or more impact experiments will be conducted. These experiments will elucidate the utility of applying the distortion correction within the operational data assimilation cycle, and provide quantitative measures of the improvements in forecast skill in the selected cases. The algorithm will be extended to allow for operational implementation. Tuning of the algorithm will be refined. In addition the algorithm will be made more efficient. Finally, the operational algorithm will undergo pre-implementation testing. This involves running a parallel data assimilation cycle which includes the operational distortion correction algorithm and comparing the resulting forecasts to the corresponding operational forecasts. Parallel runs will be performed using the Navy operational data assimilation and forecast system, with the cooperation of Naval Research Laboratory (NRL) personnel.

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APPROACH

In HG96 the method for shifting the background field is formally defined in terms of a distortion field, consisting of a field of horizontal displacements and amplification factors that are applied to the background. The distortion field is required to be large-scale and smoothly varying, and represented in terms of a spectral expansion in sines and cosines defined over the domain of interest. The distortion is determined by minimizing an objective function which constrains the distorted background field to closely fit the SSM/I data, and ensures that the final distortion produced by the minimization is relatively smooth and not too large. In HG96, the method was applied to SSM/I observation of IWV and large-scale analyses which did not use these data. In the present project, we adapt this method to adjusting the first guess field of the COAMPS data assimilation cycle. Short-term COAMPS forecasts used as the background field in the COAMPS analysis are distorted for a better fit with the SSM/I data over the ocean, and subsequently used in the COAMPS analysis.

WORK COMPLETED

Work during the past year has concentrated on two aspects: Case Study Selection and Algorithm Development. To select appropriate cases for study, we have obtained and examined daily operational Navy analyses and forecasts over the West Coast, along with imagery of SSM/I IWV retrievals. Our primary area of interest is the current COAMPS domain over the West Coast of the United States. For initial testing of our algorithm, we obtained COAMPS forecasts and SSM/I observations from NRL for two cases (9 January 1997 and 11 January 1997). We have identified several additional cases with clearly visible signatures in the IWV data, and interesting synoptic situations representing significant forecast challenges. A more detailed evaluation of possible candidates for the impact study cases is under way.

The algorithm was adapted to the different domain and format of the COAMPS model background field, and enhanced to improve its efficiency. In the present implementation, IWV is computed from the COAMPS model fields (on the COAMPS grid and vertical coordinates), and matched against all available SSM/I observations of IWV within the model domain. Differences in the valid time of the forecast and observations are taken into account by performing a linear interpolation in time between adjacent forecast times. The minimization of the objective function was changed from a routine which uses only function values to one which uses both function and gradient values. For this purpose, the adjoint of the objective function calculation was implemented. Together these changes resulted in significant speedups of the computation.

RESULTS

A number of experiments were conducted to determine the distortion. These experiments serve to test the implementation of the algorithm, to determine its correctness and to

identify areas in need of improvement or parameter tuning. We used COAMPS fields for 11 January 1997 for a series of simulation tests. In these experiments, the 12-hour COAMPS forecast fields were used to compute the background field IWV. SSM/I observations were simulated from the same field, assuming observation locations at selected model gridpoints, and applying a known distortion field to the COAMPS field to compute "observed" IWV values. In the first of these experiments, a very simple distortion field was applied to simulate the SSM/I data: a positive amplification, and a southeastward displacement, both of which were maximized at the model domain center and vanished at the boundaries. The minimization software correctly recovered the specified distortion to within a few percent, and reduced the mismatch in the IWV by a factor of 60. The solutions obtained using function values either with or without gradient values, were virtually identical.

In a second experiment, a distortion field with more horizontal structure was applied to the COAMPS field to define the simulated observations. In this case, the minimization algorithm was also able to reduce the mismatch between the initial COAMPS field and the simulated observation, but it did so with a distortion field that differed from the one used to compute the simulated observations. This result illustrates the fact that there may not always be unique solutions: depending on the characteristics of the gridded and observed fields, different distortion fields may be able to produce similar distorted values at the observation locations. We will explore this aspect further using data from actual rather than simulated observations.

We tested the software that applies the distortion to the original COAMPS model fields (as opposed to the IWV fields derived from it). For this test, we applied the full distortion to the vapor pressure field, and the displacement only to the perturbation pressure and potential temperature fields. The IWV field calculated from the distorted COAMPS fields agrees closely with that obtained by distorting the IWV field directly.

IMPACT

The results obtained so far validate our approach, but do not yet have a direct impact on Navy operations.

TRANSITIONS

Our strategy for technology transition has both short-term and longer-term aspects. In the short term we expect that, if our project proves successful, the Navy will be interested in inserting a distortion step in the COAMPS data assimilation system. In addition for the Navy there are potential applications for TESS and NOGAPS. For this reason we have included provisions for both case study impact tests and a preoperational parallel-run evaluation.

Our medium term goal is to develop other applications of our method. We would first generalize the method to use all available observations to define the distortion. This will best be done in the context of 3- and 4-dimensional variational data assimilation, currently being developed at various centers. Further generalizations of the method potentially make it suitable for a range of other applications, ranging from the fusion of radar and satellite images of precipitation, to medical imaging, to machine vision.

RELATED PROJECTS

There are a number of AER projects closely related to this project. In a study sponsored by NASA we are evaluating the distortion methodology to characterize the properties of model forecast error from the Goddard EOS global model. AER is also a member of the NASA Scatterometer Science Team. AER's primary goal is to investigate the application of scatterometer data in numerical weather prediction models. We are focusing on algorithm development for scatterometer data retrieval, ambiguity removal, fusion with other sensors, and assimilation by numerical weather prediction models. In another project sponsored by NASA we aim to optimize the use of scatterometer data for NWP purposes by combining the SeaWinds scatterometer data with data from other microwave sensors. There is a close relationship between these projects and the current work since the scatterometer, like the SSM/I, has the potential of detecting oceanic storms. In addition, we have conducted several projects investigating the use of optimum interpolation for global and mesoscale data assimilation, and the use of satellite data in data assimilation.

REFERENCES

Descriptions of this and other projects can be found on AER's home page: <http://www.aer.com>, by selecting "Groups", "Numerical Weather Prediction", and "Major Projects" (<http://www.aer.com/groups/nwp/m-proj/m-proj.html>).

R. N. Hoffman and C. Grassotti, 1996: A technique for assimilating SSM/I observations of marine atmospheric storms. *J. Applied Meteorol.*, 35, 1177—1188.