Shipboard Data Assimilation System/Doppler Radar

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LONG-TERM GOALS

Develop a high-resolution data assimilation system that can provide an analysis of the atmosphere with sufficient details and accuracy that it can be used to support the Navy mission in threat detection, weapons, and weather safe operations. The system will utilize all available weather information, such as Doppler radar, in situ, and remotely sensed observations, to generate a detailed analysis of the atmosphere with sufficient accuracy to predict Electro-Magnetic/Electro-Optical (EM/EO) propagation and potential weather target conditions. This information can then be fed back to the SPY-1 radar and other weather systems, to give them lower threshold detection capability.

OBJECTIVES

Build a data assimilation suite around the Coupled Ocean/Atmospheric Mesoscale Prediction System (COAMPS). This data assimilation system will be able to analyze mesoscale weather by applying sophisticated analysis procedures capable of ingesting the information from Doppler radar, mesonet, and remote sensors. The primary focus of this effort will be to design a system that optimally utilizes the available weather information such as SPY-1 Doppler radar for COAMPS.

APPROACH

A mesoscale data assimilation system is being jointly developed by NRL and the University of Oklahoma, which uses the background fields provided by the atmospheric component of COAMPS predictions on non-synoptic time levels and the newly developed NRL Atmospheric Variational Data Assimilation System (NAVDAS) on the synoptic time levels. This new and complementary variational assimilation system (3.5DVAR) uses simplified adjoint methods to achieve the high computational efficiency needed to assimilate high resolution data from Doppler radars (including SPY-1) in four dimensions (space and time). The analysis increment fields are expressed by B-spline basis functions to optimally filter noise while the analysis is performed directly on the COAMPS grid. The assimilation time window is synchronized with COAMPS integration time steps and radar volumetric scans to enhance the coupling of the model with the data.

To compliment the radar assimilation system, a separate cloud analysis package is used to analyze the high-resolution geostationary satellite observations (such as the GOES IR and visible imagery) and reflectivity data from radars. The cloud analysis provides estimates of cloud water and ice over a much larger region than is possible from using the 3.5DVAR system with the radar data alone.

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WORK COMPLETED

SPY-1 radar reflectivity and Doppler radial wind data, collected during the US Navy's At-Sea Demo field experiment in September of 1999, was obtained from Lockheed Martin, processed and compared with NEXRAD data (NOAA's operational Doppler radar) for the case of a squall line off the coast of Jacksonville, Florida. The 3.5DVAR wind and temperature retrieval scheme was successfully tested with both the SPY-1 and NEXRAD radial wind during this field experiment. This is the first time that Doppler radial wind data obtained from a SPY-1 radar have been used to analyze the wind corrections from a squall line for a COAMPS background forecast.

The GOES cloud analysis scheme, adapted for COAMPS from the University of Oklahoma ARPS Data Analysis System (ADAS v2.3), was successfully transitioned into an operational nowcast capability for use with the on-scene version of COAMPS. Hourly cloud analyses are now routinely produced on a local workstation utilizing the operationally available GOES IR and visible imagery to correct the COAMPS predicted cloud fields (see Fig. 1). Further improvements were made in the IR radiative transfer model used in the cloud analysis. An improved cloud top temperature was produced and a new solar angle adjustment added to the scheme. To improve the surface temperature estimates

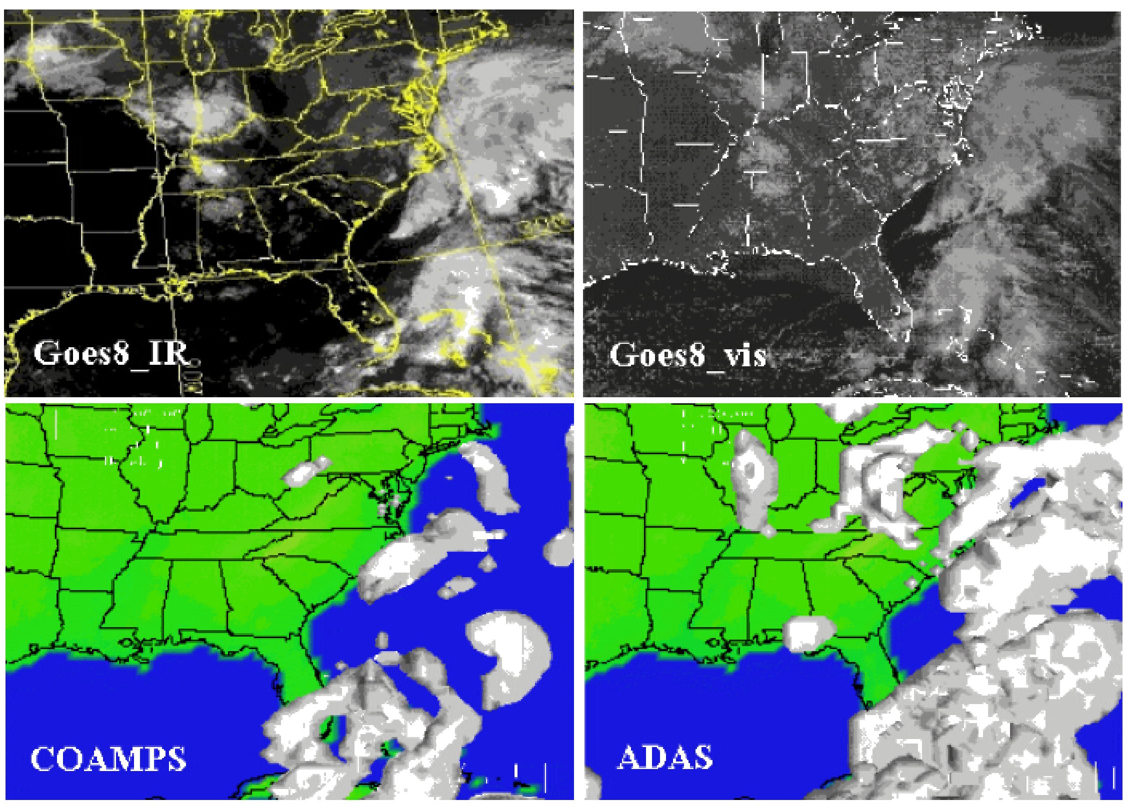

Fig. 1. GOES8 IR and visible images, and 3D clouds from the COAMPS forecast and the ADAS cloud analysis for 19Z August 28, 2000.

and forecasts by COAMPS, a separate surface skin/canopy layer was added to the ARPS soil-vegetation model package (Xue et al. 1995), which will run in COAMPS. In the modified package, the surface skin temperature is now diagnosed from the surface energy balance. The resulting improved predictive capability of COAMPS will allow for generating better land surface properties for the simulation of GOES cloud imagery used as background information by the cloud analysis over land.

RESULTS

Both the 3.5DVAR radar assimilation system and the ADAS cloud analysis were tested with the data obtained from the Jacksonville squall line case for 9-10 September 1999 during the At-Sea Demo field experiment. Cloud analyses, produced by updating COAMPS cloud forecasts with GOES 8 IR and visible imagery, compared well with the independent RT-NEPH cloud analyses produced by the US Air Force. A series of 5 hourly ADAS cloud analyses were used to correct a COAMPS integration starting at 12Z September 9. Precipitating clouds, which had been absent in the COAMPS integration, were successfully assimilated during an initial 5-hour period of assimilation in which cloud fields were updated at each hour of the model integration. The improvements in precipitating clouds remained significant during the subsequent 5 hours of the forecast after the end of the assimilation period at 17Z. For longer forecasts, differences between runs with and without the addition of the clouds from the ADAS analysis became insignificant. The positive impact on the COAMPS forecasts of precipitation was therefore largely seen during the first 5 hours of the forecast.

The 3.5DVAR radar assimilation code was tested with SPY-1 and NEXRAD data for the same case. The squall line was clearly observed by both radars, with the NEXRAD scanning the squall line from the west and the SPY-1 scanning it from the east. The reflectivity patterns observed by both radars in the middle of the troposphere at 0:58Z on 10 September are shown in Fig. 2.

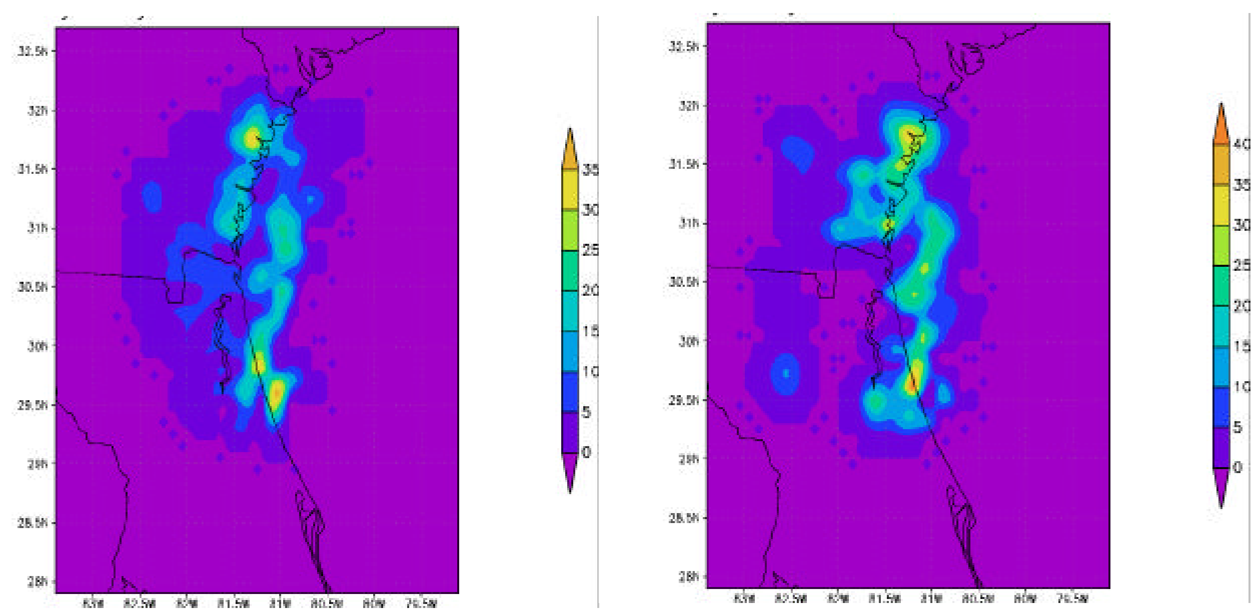

Fig. 2. The reflectivity interpolated to a height of 5.8 km for the SPY-1 radar (left panel) and for the Jacksonville NEXRAD radar, KJAX (right panel) on 00:58Z September 10, 1999. The SPY-1 radar is situated east of the squall line about 100 km offshore of Jacksonville Florida on a Navy AEGIS cruiser. The reflectivity scale in dBZ is shown to the right of each panel.

The patterns generally agree in the main features of the squall line. The SPY-1 radar misses some of the lighter precipitation falling over the land, due partly to attenuation of the radar signal by the squall line and to the cut-off signal to noise ratio used in the declassified SPY-1 signals. With better processing of the raw SPY-1 signals, better range discrimination should result. The wind field increments retrieved by 3.5DVAR from the SPY-1 radar and separately from the NEXRAD radar are compared in Fig. 3 for the same time as in Fig. 2. For the retrievals, a background COAMPS forecast is produced by a 12-hour forecast starting at 12Z September 9, followed by an operational analysis at 00Z on September 10, and by a further one hour forecast integration. For each radar, a definite radial bias in the direction of that particular radar can be seen in the retrieved horizontal wind increment. The squall line was not present in the COAMPS background forecast, so that the only information on the squall line used in each retrieval comes from the radial wind data used from just three scans by each radar. In spite of the radial bias, the addition of the retrieved wind increments to the COAMPS forecast produced precipitating cloud cells that persisted for several hours of integration in locations of the observed clouds and with similar intensities. However the cells produced in the weaker region of accent just south of Jacksonville (in Fig. 3) in the SPY-1 wind retrieval case were somewhat weaker, as might be expected.

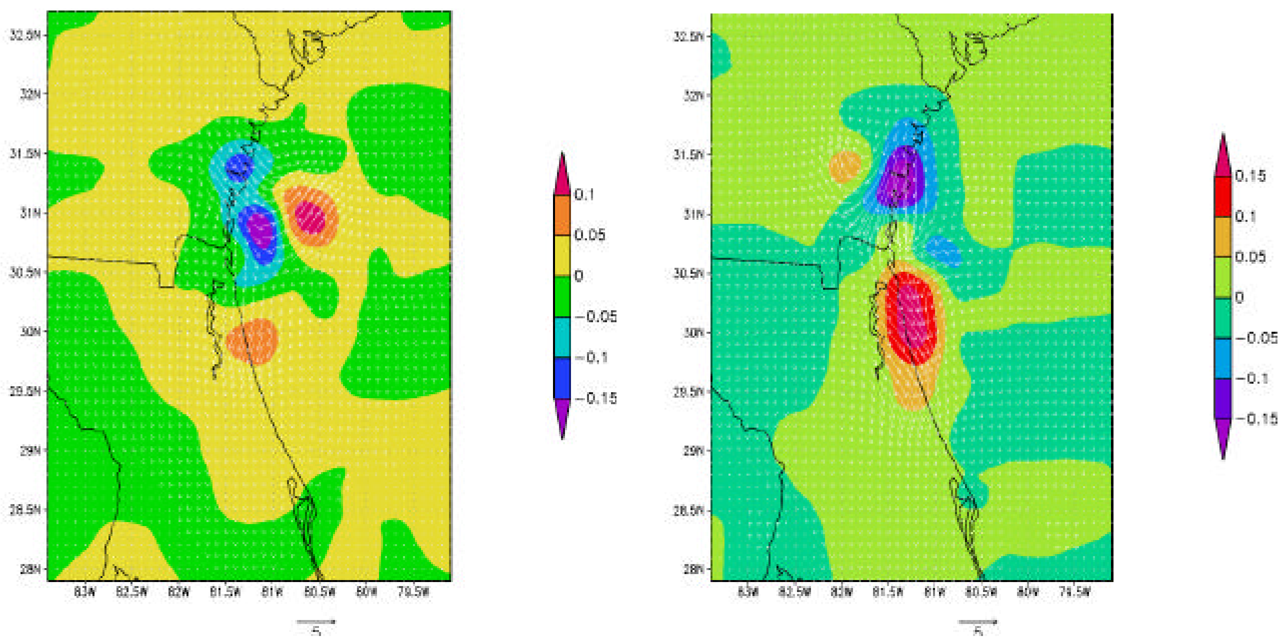

Fig.3. The retrieved three-dimensional wind field increments analyzed at a height of 5.8 km for the SPY-1 radar (left panel) and for the Jacksonville NEXRAD radar (right panel) on 00:58Z September 10, 1999. The labeled (5 m/s) arrow below each figure shows the scale of horizontal wind vectors, while the color contours of vertical motion (in m/s) are shown to the right of each panel.

IMPACT

The newly developed assimilation of the high resolution Doppler radar data (3.5DVAR) in combination with all other available weather information is expected to lead to a significant improvement in the quality of the COAMPS on-scene atmospheric environment analysis and forecast. Improvements in on-scene COAMPS translate to improved tactical mission support and cost savings for the Navy.

TRANSITIONS

The ADAS cloud analysis and the GOES IR forward model computer codes, adapted under this project, have been successfully integrated into COAMPS. The new capabilities are being tested in 6.4 programs

(PE 0603207N, SPAWAR PMW-185) for applications within the On-Scene Tactical Atmospheric Forecast Capability and, via the TESS/NC - JMCIS link, with the tactical applications supporting on-scene decision-makers.

RELATED PROJECTS

Related NRL projects include BE-35-02-19, Data Assimilation and Analysis; BE 033-03-42, Multidimensional Data Assimilation Methodologies, and BE 35-2-56, Nowcasting the Atmospheric Battlespace Environment. Other related projects at NRL are funded by ONR (Nowcast for the Next Generation Navy) and SPAWAR PMW-185, task X2342 under PE 0603207N (Variational Assimilation and Physical Initialization; On-Scene Tactical Atmospheric Forecast Capability.

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