P3.15

USE OF SATELLITE-DERIVED ATMOSPHERIC MOTION VECTORS IN SIMULATIONS OF CYCLONES DURING PACJET

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1. INTRODUCTION

The objective of this work is to estimate the impact of the assimilation of satellite-derived atmospheric motion vectors (AMVs) on 36 hour simulations of poorly forecasted cyclones in the eastern Pacific and near the west coast of the United States during the PACific landfalling JETs (PACJET) experiment. Initial conditions for these simulations are determined using adjoint-based sensitivity gradients and observational analysis. The estimates will then be verified through four-dimensional variational (4DVAR) data assimilation of the observations.

The PACJET experiment took place from January through March 2001 and 2002. This experiment featured enhanced observations in both space and time from dropsondes and wind profilers. The goal of PACJET was to improve short-term forecasts of damaging weather on the U.S. West Coast. The GOES rapid scan WINDs EXperiment (GWINDEX) was a part of PACJET. The goal of GWINDEX was to provide improved wind estimates over the data sparse northeast Pacific Ocean (Velden et al. 2001).

In the following presentation, the observational data and models used will be described. Then results from a case study will be presented along with initial work and expected results based on the findings.

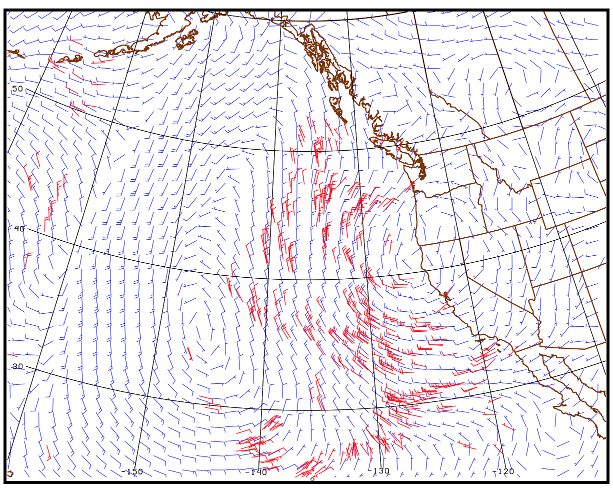

Figure 1. 850 hPa AMVs (red) and AVN wind analysis (blue) in ms^{-1} for 0000 UTC 12 February 2001.

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2. DATA

The principal data type that will be used in this study is satellite-derived AMVs. These AMVs are derived at the University of Wisconsin - Madison/CIMSS from 7.5 minute interval rapid-scan visible and infrared imagery from the GOES-10. Water vapor and clouds are tracked in three sequential images to generate three-dimensional distributions of estimates of the wind products. These enhanced winds were available hourly in 2001 and every three hours in 2002. Figure 1 shows an example of AMVs in a 50 hPa layer centered around 850 hPa at 0000 UTC 12 February 2001 (red) along with the NCEP Aviation model (AVN) wind analysis at 850 hPa valid at the same time (blue).

Dropsonde data and wind profiler data were also available as a part of the PACJET experiment. The wind profilers are located along the west coast of the U.S. The wind values represent hourly averages, and there is data every 50 hPa from the surface to 100 hPa. Dropsondes provide wind measurements at nearly every level from the surface to about 500 hPa.

The observations will be used for a number of purposes in this study. Observations that are co-located in time and space can be compared to each other to help determine weights for use in the data assimilation system. The observations can also be assimilated to change the initial conditions of the simulations. Finally, unassimilated observations may be compared with the simulation to determine its accuracy.

3. MODEL AND DATA ASSIMILATION SYSTEM

The numerical weather prediction (NWP) model used in this study is version 2 of the Pennsylvania State University-National Center for Atmospheric Research (PSU-NCAR) non-hydrostatic mesoscale model (MM5v2). It is run with a 60 km horizontal resolution using the Kuo cumulus parameterization scheme, simple ice physics, and bulk-aerodynamic flux formulation for the planetary boundary layer. The simulations are initialized using the AVN final analyses. The MM5 Adjoint Modeling System (MM5 AMS) used for the sensitivity studies is run "dry" about a moist basic state (Zou et al. 1997).

In order to assimilate the AMVs a forward operator of the AMVs is being developed for the MM5 AMS. The 4DVAR data assimilation system currently uses a background error covariance matrix, which is determined from a comparison of the initial conditions and a short forecast. At present, one value is used to weight all of the AMVs. Both the background error covariance matrix and the weight for the AMVs is chosen for simplicity; other ways to determine these will be investigated in future work.

4. CASE STUDY

Three cases are currently being used in this study. For this preprint one particular case will be described, and the others will also be included in the poster presentation. This case involves a cyclone that deepened approximately 17 hPa during the period 0000 to 1200 UTC 13 February 2001 off the shore of California. This cyclone was accompanied with heavy precipitation and strong winds.

36 hour forecasts of this event by operational NWP models as well as an initial MM5v2 research simulation failed to fully deepen the cyclone (Fig. 2). The research simulations of this event used 68 x 85 horizontal grid points and 16 half-sigma levels.

The response function for the adjoint model is described as the energy weighted error in a box that encompasses the analyzed cyclone (Fig. 2 top panel).

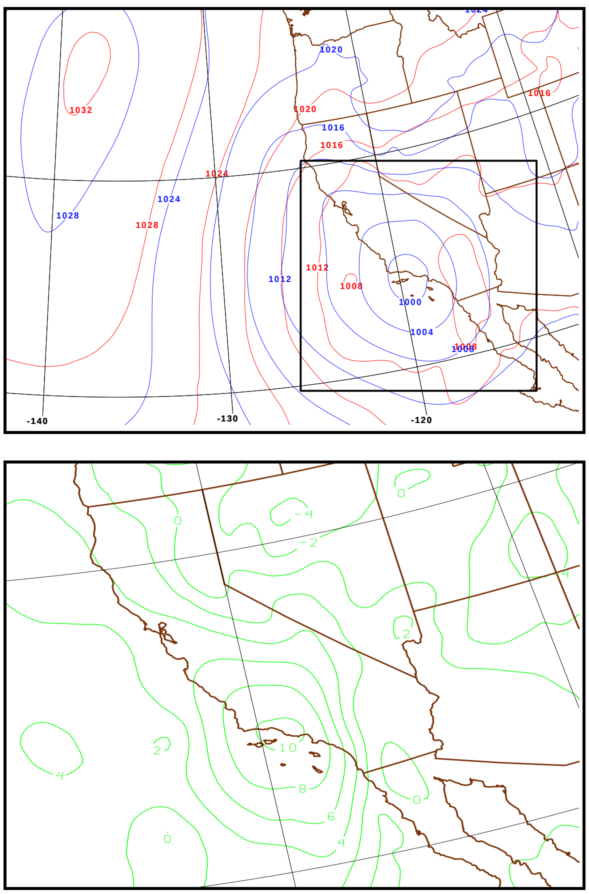

Figure 2. 1200 UTC 13 February 2001. Top panel: Mean sea level pressure (contour interval 4 hPa) from the AVN analysis (blue) and the MM5v2 36 h forecast (red). The square denotes the domain in which the energy weighted error was calculated. Bottom panel: Mean sea level pressure difference (contour interval 2 hPa) from the top panel.

5. INITIAL WORK

The adjoint model is used to compute the sensitivity of the response function with respect to the zonal and meridional wind. An observational increment is determined by subtracting the analyzed winds, interpolated to the AMV locations, from the AMVs. These observational increments are objectively analyzed using the Barnes scheme, resulting in the analysis increments. The inner product of the analysis increment and the sensitivity gradients provides an estimate on how the response function will change. In this case a decrease in the response function means that the forecast error will be reduced if the analysis increment is used to change the initial conditions.

Figure 3 depicts the sensitivity gradients (top panel shows the full domain) and observational increments for the zonal wind at 850 hPa. Note that the large region of positive sensitivity gradients coincides with mainly positive observational increments. This suggests an increase in the forecast error would result from assimilation of these wind components. This does not mean that all of the observations in this case will result in an increase in forecast error. Sensitivity gradients possess a baroclinic tilt (not shown) so the extrema at one level do not necessarily coincide with the extrema at other levels. Also the observational analysis is not necessarily co-located with the sensitivity gradients. Finally, the sensitivity gradients are maximized around 700 hPa where there are relatively few observations (Fig. 4).

Two modified simulations were performed to determine how changing the initial conditions would alter the resulting forecast. The first simulation consisted of multiplying the sensitivity gradients by a scaling factor and subtracting that value from the initial conditions. This resulted in a new set of initial conditions, which were used to run the simulation. This is similar to the method of determining the key analysis errors, which iterates the process of calculating sensitivity gradients and determining new initial conditions. The second simulation consisted of objectively analyzing the AMVs to the grid point locations. Those values were used in place of the initial conditions where applicable, and once again the new initial conditions were used to run the simulation. This is not the same as data assimilation because no weighting was given to the AMVs. Also the goal of this simulation was to get a quick idea of the influence that the AMVs would have on the forecast. Both simulations resulted in weaker cyclones than the original simulation (as measured by mean sea level pressure) with a minimum mean sea level pressure of around 1008 hPa.

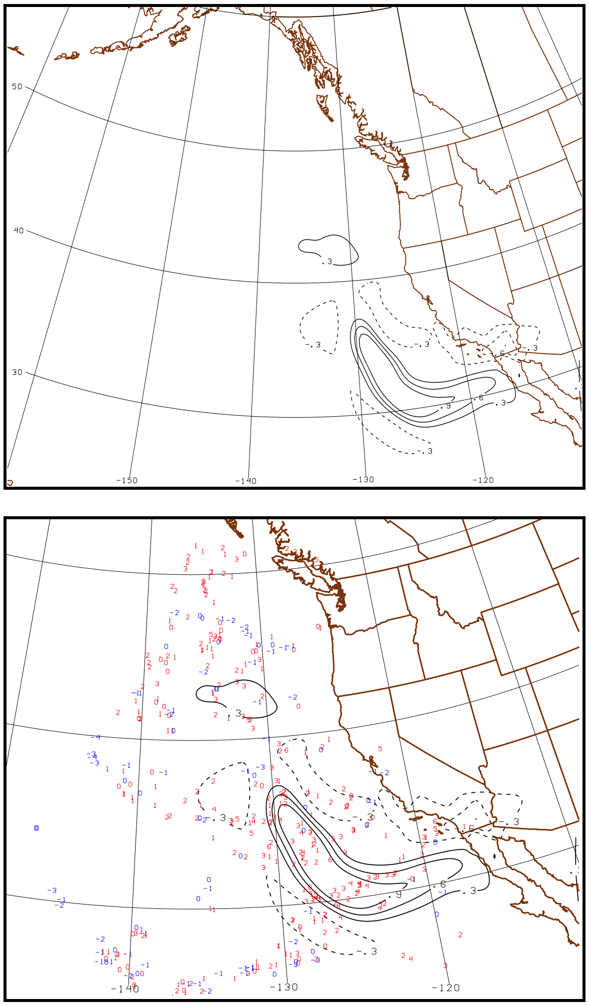

Figure 3. 0000 UTC 12 February 2001 at 850 hPa. Sensitivity of energy weighted error with respect to the zonal wind (contour interval .3, negative values are dashed). Numbers in ms^{-1} represent positive (red) and negative (blue) analysis increments. The top panel shows the full domain.

6. EXPECTED RESULTS AND SUMMARY

Based on the two modified simulations it is expected that assimilation of the AMVs into the MM5 4DVAR system will have a slight negative impact on the forecast for this case. Forthcoming results for the case discussed as well as the other cases will be presented on the poster.

A number of key observations can be made based on the work to date. The extrema in sensitivity gradients do not necessarily coincide at different levels due to the noted baroclinic structure of the sensitivity field. The maximum number of observations (found in the lower troposphere) do not coincide with the largest sensitivity gradients (found in the middle troposphere). The existence of many observations that are not in sensitive regions suggest that adding this information will not strongly influence the energy weighted error.

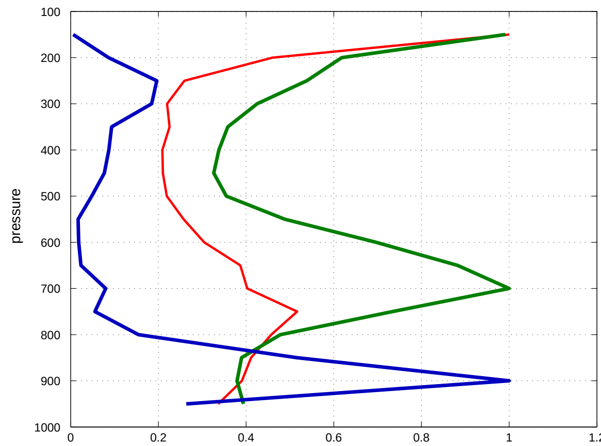

Figure 4. The vertical distribution of the sensitivity of energy weighted error with respect to the zonal wind (green), meridional wind (red), and observations (blue). The sensitivity gradients are normalized to their maximum value, and the observations are normalized to the maximum number of observations (1,831 AMVs).

The simulation that used key analysis errors found that changing the wind analysis by a few meters per second was enough to improve the forecast. It is reasonable to expect that initial conditions determined through the use of a 4DVAR data assimilation system would differ from the original initial conditions by the same magnitude. Therefore this suggests that 4DVAR data assimilation of these AMVs has potential to modify forecasts along the U.S. West Coast.

7. REFERENCES

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Acknowledgements

The authors thank Chris Velden and Dave Stettner for providing access to and assistance in using the satellite data. This work was supported by National Science Foundation grant ATM-9810916 and National Oceanic and Atmospheric Administration grant NA67EC0100.