U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE
NATIONAL METEOROLOGICAL CENTER

OFFICE NOTE 143

Test of Truncation Error Controls on "Cross Contour" Flow

Joseph P. Gerrity, Jr.
Development Division

APRIL 1977

This is an unreviewed manuscript, primarily intended for informal exchange of information among NMC staff members.

2. The Observations and the 6L PE Forecast

The area within which the erroneous wind forecast occurred is one in which observations are largely limited to those made by aircraft, satellite and surface ships. In figures 1 through 5, we show the sea level 300-mb level and IR cloud pictures for SMS2 at 12-hr intervals. The contours on the charts were drawn by NMC synoptic meteorologists. The data are plotted on the base charts by computer. The origin of the upper-air data is indicated by the plotted symbols:

A circle indicates radiosonde

A star indicates satellite observation

A box indicates an aircraft report.

At the initial time (Fig. 1), the 300-mb chart indicates the existence of a very sharp wind shift along 150°W longitude and the existence of a wind maximum (130 knots) north of Hawaii. During the ensuing 2 days, the base of the upper trough is cut off and a closed circulation develops.

In Fig. 6, the initial 300-mb data used by the 6L PE in the region of the sharp trough is shown. The data has been modified through the initialization steps of the 6-layer model involving a transfer of the isobaric analysis into the sigma coordinate of the model and an inverse transfer back to isobaric levels. The wind field is depicted by arrows in the conventional fashion except that the barbs indicate wind speed in units of meters per second. A pennant indicates 50 m sec^{-1}; a full barb indicates 10 m sec^{-1}; a half barb indicates 5 m sec^{-1}. The rather appreciable cross-contour orientation of the winds should be noted. The winds are shown only at alternate grid points.

Test of Truncation Error Controls on 'Cross Contour' Flow

1. Introduction

The 6L PE model's forecast of the 300-mb wind field valid 36 hours after the initial time of 00 GMT 17 Feb 77 exhibited a pronounced cross-height contour orientation of the isotachs (110 knots max) in the vicinity of the Hawaiian Islands. The prediction of such strongly ageostrophic flows has been a persistent problem for the past decade at NMC. The correction of this error-type is routinely made by the personnel of the Aviation Weather Branch prior to the dissemination of aviation wind forecasts.

Within the past several months NMC has attained the capability of examining the extent to which numerical truncation error is responsible for the erroneous wind prediction. At the direction of Dr. Shuman, we have used the cited synoptic case in conjunction with two numerical models that possess theoretically superior horizontal truncation error.

The HFM, hemispheric fine-mesh model, was constructed by extending the grid-point resolution of the 6L PE model so that the horizontal grid size was reduced to 190.5 km at 60°N. A second model developed by Mr. K. A. Campana uses the semi-implicit time integration method with fourth-order accurate approximations for the nonlinear advection terms. The KAC method uses a grid size of 381 km at 60°N. This KAC-4 model and the HFM model were both run on the initial data for 00 GMT 17 Feb 77 that was used by the 6L PE model.

We will show that the erroneous 6L PE forecast is corrected to a significant extent by the new models. It is also noted that the initial cause of the problem is related to the generation of a noise wave in response to an apparent imbalance of the initial data. Although the new models are subject to the same initial error, their superior numerical accuracy minimizes the local growth of an erroneous flow.

In Fig. 7, we show an analogous depiction of the 6-hr forecast produced by the 6L PE. We call attention here to the presence of a noise wave in the geopotential field between 150° and 165° west longitude along the $20^{\circ}N$ parallel.

In Figs. 8 and 9, we show the 24 and 36 hour forecasts produced by the 6L PE. The development of the unrealistic northerly jet between 150 and $160^{\circ}W$ longitude is apparent.

3. The Experiments with Truncation Error Control

In Figs. 10 and 11, we show the 24 and 36 hour forecasts produced by the hemispheric fine-mesh (HFM) model. We again observe the development of a northerly jet. The wind speed in the jet is appreciably reduced. The realism of this forecast cannot be adequately assessed from the observational data base. It does seem to the writer that the forecast is probably adversely affected by the noise associated with the initial imbalance. The northerly jet to the rear of the cut-off low is probably realistic, and is supported by aircraft winds at 24 hours.

In Figs. 12 and 13, the 24 and 36 hour forecasts produced by the KAC-4 model are shown. The results obtained are comparable to those with the HFM. The cut-off low is provided in the contour height field as well as the wind field.

Figs. 14, 15, and 16 show the full hemispheric 300-mb forecasts produced by the 6L PE, the HFM, and the KAC-4 models.

4. Conclusions and Further Work

There is clear evidence that the magnitude of the so-called "cross-contour flow" problem can be reduced by the use of truncation error controls. The near equivalence of the HFM and KAC-4 model forecasts indicate that about the same error reduction is achieved by either halving the mesh length or using 4th order finite-difference approximations.

A complete solution to this cross contour flow problem, and the possibly related problems of excessive "digging" and "locked-in error," will probably require improvements in the methods now used to initialize primitive equation models. Further work is planned in the area of research into initialization methods.

Acknowledgments

The assistance of Jack Newell, Rod Scofield, Glenn Rasch, and Ken Campana in compiling the materials used in this note was essential and was generously provided.