A note on the use of a forecast as the first guess in objective analysis[1]

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ABSTRACT

Some evidence is shown that the National Meteorological Center (NMC) objective analyses over the Pacific largely exaggerate the meridional transport of zonal momentum and on the average show the west wind maximum north of its true position. The use of numerical forecast as the first guess in the objective analysis is suggested as a possible cause of these systematic errors.

It has been recently observed that some atmospheric flow statistics over the Northern Hemisphere, as computed from the National Meteorological Center (NMC) objective analyses, deviate considerably from the corresponding quantities deduced from conventionally analyzed data. For example, it was noticed (Holopainen, 1967) that the NMC analyses give, for the mean meridional flux of zonal momentum in the middle latitudes, values which were almost two times larger than those obtained by conventional analysis techniques. The purpose of this note is to give some further numbers on this discrepancy and to suggest a possible explanation for it.

The principle of the NMC objective analysis system (Cressman, 1959) is to apply, with the aid of observations, corrections to a first-guess field, which is the numerical forecast from a synoptic time 12 hours before the time of analysis. In the regions of good data coverage (North America, Europe) the final analysis is essentially determined by observations and little influenced by the choice of the first-guess field. In such regions the difference between objective and conventional analyses is small. Any major differences must arise over areas such as Pacific where little or no observations exist. There the objective analysis is almost identical to the first guess field. This analysis is now used as an initial field for a forecast which again serves as the first guess field in objective analysis for the synoptic time 12 hours later and so on. It is quite possible that over areas of poor data coverage the errors caused by the shortcomings of the prediction model will accumulate and give systematic error in the objective analysis.

Table 1 gives the mean meridional flux of zonal momentum, $u_g v_g$ (u_g and v_g are the zonal and meridional component of geostrophic wind, respectively), across the latitude 42.5° N; according to Holopainen (1967) the apparent overestimation of momentum flux by numerical analyses is largest around this latitude.

Table 1. *Mean geostrophic poleward flux of linear zonal momentum across the latitude 42.5° N at the 300 mb in January 1964*

Unit: $m^2 sec^{-2}$

	Average around the whole latitude circle	Average between 125° W–0°–145° E	Average between 145° E–180°–125° W (Pacific)
NMC objective analysis	72	19	232
Conventional analysis (DEBENEC *et al.*, 1964)	47	16	141

It is seen from the first column of this table that the objective analyses give a much larger

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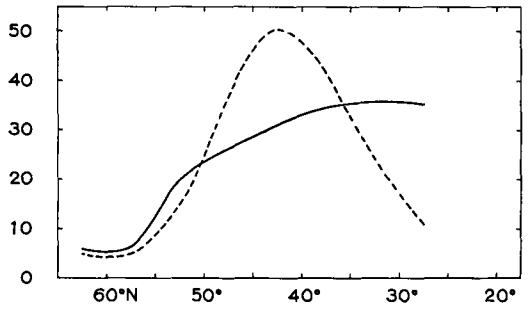

Fig. 1. Distribution of the mean zonal geostrophic wind component in January 1964 at 300 mb along the longitude 160° W. Solid line is obtained from conventional analyses (Debenec *et al.*, 1964), dashed line from NMC objective analyses of 300 mb topography. Unit: m sec^{-1}.

zonal-mean momentum flux than the conventional analyses; as can be expected, practically all the difference comes from the Pacific area (see the last two columns in the table), where the "hole" in the network of observation stations is largest over the Northern Hemisphere. One may now legitimately ask whether the conventional analyses over the Pacific can be considered superior to the numerical ones, because no data exist for a test. Here it should be remembered that more observations exist for surface analysis than for upper air analysis and that conventional analysis employs this further information, while the numerical analysis does not, at least not until recently. It is here also of interest to note that the zonal-mean momentum flux from the conventional analysis, 47 m^2 sec^{-2}, agrees well with the corresponding values which can be worked out for long-term winter conditions from the statistics published by Lahey *et al.*, (1959) and by Crutcher (1959); these values are 39 m^2sec^{-2} and 47 m^2sec^{-2}, respectively.

Another feature of the discrepancy between the objective and conventional analyses over the Pacific is seen in Fig. 1, which shows the monthly-mean geostrophic zonal wind component at 300 mb along the longitude 160° W. If we assume that the values obtained from the conventional analyses are approximately correct, we conclude that the numerical analyses largely under-estimate the zonal velocity south of about 35° N and overestimate it between about 35° N and 50° N. The difference between the two curves in Fig. 1 is not accidental but represents a real phenomen: at the latitude 42.5° N, for example, 27 out of 30 daily differences had the same sign as the monthly mean value.

From the possible causes of the apparent systematic error in the NMC objective analyses over the Pacific the most obvious one is, as mentioned earlier, accumulation of errors of the prediction model which is used to obtain the first guess to the analysis. In this respect it is of interest to note that the error in zonal wind as indicated by Fig. 1 is typically what could be expected from the use of barotropic forecast as the first guess field. A barotropic model is capable of transporting zonal angular momentum in a meridional direction but it does not include a proper mechanism for a vertical transfer of this quantity. As a consequence of this there is in the barotropic model a tendency for a spurious depletion of zonal angular momentum in the subtropics and for an accumulation of it in higher latitudes (e.g. Bristor, 1959). According to Fig. 1 this seems to be what happens in the NMC numerical analysis/forecast system over the Pacific. The model used in NMC in January 1964 was not barotropic but a three-level baroclinic one. The characteristics of this model are so far not known. Fig. 1 indicates, however, that from the point of zonal angular momentum they are likely to be similar to those of the barotropic model.

The generation of excessive momentum flux by the objective analysis/forecast system could now be qualitatively explained in the following way. On the predominantly westerly current the use of forecast as the first guess has the effect of carrying information to the western but not to the eastern part of the hole. As a consequence, the erroneous northward shift of the wind maximum increases in the hole from west to east. Obviously, this spurious SW–NE tilt of the jet leads to a positive error in the northward flux of zonal momentum in the hole.

On the basis of the above discussion it seems justifiable to suggest that the use of forecast as first-guess field in the NMC objective analysis system leads, over the Pacific, to systematic error such that westerlies are shifted north from their true position and that the meridional flux of zonal momentum becomes largely exaggerated. These errors must be important in daily forecasts for the North American area. They also become exceedingly important if these analyses are used in diagnostic studies of general atmospheric circulation.

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ЗАМЕЧАНИЕ ОБ ИСПОЛЬЗОВАНИИ ПРОГНОЗА КАК ПЕРВОГО ПРИБЛИЖЕНИЯ В ОБЪЕКТИВНОМ АНАЛИЗЕ

Показано, что объективный анализ Национального метеорологического центра над Тихим океаном сильно преувеличивает меридиональный перенос зонального количества движения и в среднем дает положение максимума западного ветра севернее его настоящего положения. Высказывается предположение, что возможной причиной таких систематических ошибок является использование численного прогноза как первого приближения для объективного анализа.