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SUMMARY OF VERIFICATION OF 30-DAY TEMPERATURE PREDICTIONS WITH THE THERMODYNAMIC MODEL OVER CONTIGUOUS U.S. FOR 1969

by

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ABSTRACT

A verification is presented of the thermodynamic model in predicting 30-day surface air temperature anomalies over the contiguous U. S. for the period December 1968 to November 1969.

Results of numerical experiments are included, which isolate the effect on the prediction of the mean-wind advection, anomalies of snow and storage of heat in the soil.

1. INTRODUCTION

30-day numerical weather prediction experiments have been carried out since December 1965, and preliminary verifications have been published (Adem & Jacob, 1968; Adem, 1969; Adem 1970a).

Besides the routine preparation of real-time-predictions for possible use in the preparation of the official forecast, a variety of options are currently being tested to determine the effect on the skill of a variety of factors. The main options tested in the numerical experiments carried out during 1969 were the inclusion or neglect of the following factors:

(a) Anomalies of snow on the ground

(b) Advection of heat by mean wind

(c) Storage of heat in the soil

The purpose of this report is to present an evaluation of the model, as well as a comparative study on the effect of these three factors, for the period from December 1968 to November 1969. Although the model predicts quantitative values of surface temperature we will test only its ability to predict the correct sign of the temperature anomalies.

2. THE MODEL USED IN THE PREDICTIONS

A description of the model is given in detail in previous papers (Adem, 1964; Adem 1965). Therefore, we will mention only the changes that have been made, which are the following:

(a) An option has been added to include advection of heat by the mean winds. This has been done in a crude way by prescribing observed monthly normal 500-mb winds. This adds additional linear terms, which depend on the first derivatives of temperature with respect to the horizontal coordinates, without changing the method of solution of the differential equation (Adem, 1965).

(b) Another addition is the optional inclusion of storage of heat in the continents. This has been done by adding the term

$\rho_c c_c h_c (T_s - T_{a_p})/\Delta t$ in the equation of conservation of thermal energy at the surface, where ρ_c is the soil density; c_c, the soil specific heat; h_c, the depth of the surface layer; T_s, the surface temperature for the month for which the prediction is made; T_{ap}, surface air temperature in the previous month and Δt, the time interval (one month). We have used the values $\rho_c = 1.43$ gm cm^{-3}, $C_c = 0.2 \times 4.187 \times 10^7$ cm^2 sec^{-2}(°K)$^{-1}$ and $h_c = 10^2$ cm.

3. EFFECT OF SNOW IN THE GROUND

The existence of an abnormal snow boundary at the end of the previous month, as shown in some illustrative examples (Adem, 1964, Adem & Jacob, 1968, Polger, 1968), has been used successfully to predict some important changes in the surface temperature, especially when the departure of the snow boundary from its normal position is exceptionally large. However, as pointed out by Polger (1968) the incorporation of the anomalies, especially when they are small, can often hurt the predictions.

The effect of including anomalies of snow on the ground in the predictions for 1969 is summarized in table 1, which shows the percentage of signs of the surface-air temperature anomalies which were correctly predicted over the contiguous U.S.

The first and second columns of numbers show the values corresponding to the predictions when the anomalies of snow are included and neglected respectively. Their difference (third column) shows that the inclusion of snow anomalies decreases the skill of the predictions in the Winter. However, in Spring the skill was better when snow was included. In Fall the snow effect was not significant. Considering the average value for the whole year, the predictions which included snow anomalies show a slight improvement over those in which snow is neglected.

4. EFFECT OF ADVECTION BY MEAN WIND

The effect on the predictions of advection of heat by the mean wind is summarized in table 2.

The first and second columns of numbers show the values corresponding to the predictions when the advection by mean wind have been included and neglected respectively; their difference (third column) shows that the inclusion of advection by mean wind increased substantially the skill of the predictions for all seasons, except for Spring when no difference exists.

In all the predictions of table 2 the anomalies of snow on the ground were included, and were the dominant factor in Spring.

5. EFFECT OF STORAGE OF HEAT IN THE SOIL

In table 3 are shown the results of predictions in which both advection by mean wind and anomalies of snow cover are included. The values in the second column are the same as those in the first column of tables 1 and 2. These cases neglect the storage of heat in the soil, while the values in the first column also include the storage of heat in the soil. The difference of the two sets of values (third column) shows that the effect of the inclusion of storage of heat in the soil is to increase slightly the skill in Spring. However in Summer and Fall the skill is decreased. The effect in Summer is the largest one, showing a substantial decrease of skill. The effect in Winter is not significant.

6. SKILL IN FORECASTING SURFACE AIR TEMPERATURE

To evaluate the skill of the model we shall compare the predictions with those obtained using persistence as a control (i.e. using the sign of the anomaly for the previous month as the prediction), and also with the official predictions published in the Average Monthly Weather Outlook. Since the model has been run for calendar months only, we shall of course include only the corresponding cases of the official predictions.[1]

The results of the evaluations are summarized in table 4 which shows the percentage of signs (out of a total of 100 points within the contiguous U.S.) of monthly surface temperature anomalies correctly predicted.

The first column shows the values corresponding to persistence (using as predictions the observed signs of the anomalies for the previous month).

The second and third columns show respectively the values of the excess over persistence when the model includes advection by mean wind and anomalies of snow cover, and when the model is the one that was used for the real-time predictions supplied to the forecaster for possible use in the preparation of the official forecast.

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[1] Recently we started to run the thermodynamic model twice a month on a real time basis.

The differences between the values in the second and third columns are due to variations in the options used for the predictions. The main difference is in the Fall values, and is due to the fact that for October and November 1969 the model without advection was used in the predictions of the third column.

Finally, in the fourth column are shown the values of the excess over persistence of the official forecast. Comparison with the results in the second and third columns shows that, except for Fall, the skill of the model was comparable to that of the official forecast for the year 1969.

7. PLANS FOR FUTURE WORK

Research is being carried out aiming at developing a more sophisticated model, with improved parameterizations of the heating functions.

The immediate plans are to test a similar model to the one used in the above experiments; in which the main additions are the inclusion of advection of heat by ocean currents (Adem, 1970a), and a variety of options for the advection of heat by the mean wind (Adem, 1970b). These changes hopefully will increase the degree of predictability achieved.

Improvement of the skill of the model may come also from improvement of the data used.

With the present 512 point grid, the model can not adequately incorporate the anomalies of snow, because the grid distance is too large to properly describe such anomalies. Experiments with the NMC 1977-point grid, in which the distance between grid points is half that in our system, will be undertaken in the near future.

Finally, more sophisticated methods of treating the snow-cover anomalies will also be tested (Clapp, 1968).

TABLE 1.--Effect of the anomalies of snow on the percentage of correct sign of monthly temperature anomalies predicted by the thermodynamic model during 1969.

	Anomalies of snow included	Anomalies of snow neglected	Difference
Winter	57.7	64.0	-6.3
Spring	47.3	39.0	8.3
Summer	---	---	---
Fall	51.0	51.3	-0.3

TABLE 2.--Effect of the advection by mean wind on the percentage of correct sign of monthly temperature anomalies predicted by the thermodynamic model during 1969.

	Advection included	Advection neglected	Difference
Winter	57.7	47.3	10.4
Spring	47.3	47.3	0
Summer	61.3	45.3	16.0
Fall	51.0	34.7	16.3
Average for 1969	54.3	43.8	10.7

TABLE 3.--Effect of the storage of heat in the soil on the percentage of correct sign of monthly temperature anomalies predicted by the thermodynamic model during 1969.

	With Storage	Without Storage	Difference
Winter	58.3	57.7	0.6
Spring	50.3	47.3	3.0
Summer	55.0	61.3	-6.3
Fall	48.0	51.0	-2.7
Average for 1969	52.5	54.0	-1.8

TABLE 4.--Percentage of correct sign of monthly temperature anomalies predicted by the model, by persistence and by the Official Forecast, during 1969.

	Persistence	Model with Advection Minus Persistence	Real-time Model Prediction Minus Persistence	Official Prediction Minus Persistence
Winter	57.0	0.7	1.0	2.0
Spring	43.0	4.3	5.6	8.3
Summer	46.7	14.6	14.6	22.0
Fall	49.3	1.7	-7.0	12.0
Average for 1969	49.0	5.3	3.6	11.0

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