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

OFFICE NOTE 151

Evaporation in the LFM

Joseph P. Gerrity, Jr.
Development Division

JUNE 1977

Evaporation in the LFM

1. Introduction

When cold dry air flows over a warmer water body, one observes a significant transfer of sensible heat and water vapor to the air. In the present LFM model this process is modeled by transferring heat to the boundary layer at a rate proportional to the difference between the sea surface temperature TS and the boundary layer potential temperature TB, and by constraining the relative humidity of the air not to become less than 30%.

In some cases, the modified air moves back over the land. It is sometimes found that the limit RH $\geq$ 30% has been an inadequate parameterization of the moistening of the air in its passage over the sea.

A feasible scheme to correct this deficiency of the model is proposed in this note.

2. The Evaporation and Sensible Heat Parameterization

The LFM now includes a parameterization of sensible heat transfer to the boundary layer air from the warmer sea surface. The formula may be expressed (cf. Shuman and Hovermale, p. 533)[1]

$$\frac{\partial TB}{\partial t} = K_H(TS - TB)$$

K_H is a constant $10^{-4}\mathrm{sec}^{-1}$.

We propose to incorporate an analogous term in the equation governing the boundary layer "precipitable water" WB. Let WS be the saturation "precipitable water" content of an equivalent boundary layer if the temperature was that of the sea surface. We propose the formula

$$\frac{\partial W}{\partial t} = K_H(WS - W)$$

---

[1]Shuman, F. G. and J. B. Hovermale, 1968, JAM, 7:4, 525-547.

3. Some Details

If TS is given, one may calculate WS by the formula

$$WS = \frac{\Delta p}{g} q_s \quad [\text{gm cm}^{-2}]$$

with $$\Delta p = 5 \times 10^4 \quad \text{gm cm}^{-1}\text{sec}^{-2}$$

$$g = 980 \text{ cm sec}^{-2}$$

and $$q_s \cong \frac{.621}{10^3} \left[6.11 \quad 10^{\left(\frac{7.5(TS-273)}{TS-36.}\right)}\right]$$

The evaporation may be calculated in subroutine TEND5 just after the sensible heat is calculated (ISN0021; Nov 76 listing). One must modify the list of subroutine TEND5 to incorporate WS(1,1,J1) dimensioned (53,9) which contains the n-1 time level of the precipitable water.

At the point noted in TEND5, one has available the sea surface temperature from which one may calculate the saturation parameter WS corresponding to the sea surface temperature. Space averaging of W^{n-1} is omitted.

The formula for evaporation may be evaluated and stored in a field of dimension (53) that is readily transferred to TEND6 via labelled common 'WKAREA.'

The application of the evaporation to the marching of the W field can be done in 'TEND6' at the ISN 0074 where the "time averaging" takes place. This would restrict its application to after the first hour when ITSW is set to 4.

4. Implications of Formulas

It is worth noting that both formulas--sensible heat and evaporation--imply that the difference between the boundary layer θ, W and the sea-surface T,WS approach zero exponentially. Since WS and TS are independent of time,

$$\frac{\partial(TS-TB)}{\partial t} = - K_H(TS-TB)$$

$$\frac{\partial(WS-W)}{\partial t} = - K_H(WS-W)$$

$$\begin{matrix}(TS-TB) \\ (WS-W\end{matrix} \sim e^{-K_H t}$$

For $K_H = 10^{-4} sec^{-1}$, the initial differences are reduced by an order of magnitude in just 6.4 hours. This seems too fast to this writer, so some experimentation with smaller values of K_H (perhaps as small as 10^{-5}) seems to be in order. If $K_H = 10^{-5}$ it would require 64 hours to reduce initial differences by an order of magnitude.

It also seems to be desirable to restrict evaporation to cases in which sensible heat is being transported from the sea to the boundary layer. This condition is easily implemented in the proposed code.

More elaborate formulas to make K_H dependent upon stability and wind speed are perhaps too difficult to incorporate in the present LFM code.