UNIFIED MODEL DOCUMENTATION PAPER NO 50

APPLICATION OF SURFACE HEAT AND FRESH WATER FLUXES

by

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Part 1

14th September 1990

Ocean Model Documentation

Modification Record		
Document version	Author	Description....................

Application of surface heat and fresh water fluxes

Introduction

Surface fluxes of heat and fresh water are applied to the ocean model. The purpose of this routine is to increment the values of temperature and salinity in the first model layer.

Implementation

The temperature of the upper layer changes according to:

$$\Delta T = Q_n \delta t / (\rho_o c_p \Delta z) \qquad (1)$$

where the change in temperature is ΔT, the non-penetrative heat flux is Q_n, ρ_o is a reference density, c_p the specific heat capacity (assumed to be constant), and Δz the thickness of the upper layer.

Salinity is updated by assuming that the volume of the upper layer remains constant (as required by the rigid lid approximation), but that the layer becomes more or less saline by mixing the salt in the grid box uniformly throughout the layer after the fresh water flux has been added to the layer, and then removing or adding water of that salinity to ensure the volume of water in the grid box is unchanged.

Thus, if the fresh water flux is F, and the salinity of the layer is initially S_o, and after the flux is added it becomes S_1, then

$$S_1 (\rho_o \Delta z) = S_o (\rho_o \Delta z - F \Delta t)$$

ie

$$\Delta S = - S_o F \Delta t / \rho_o \Delta z \qquad (2)$$

where $\Delta S = S_1 - S_0$.

In deriving (2), it should be noted that the model has a rigid surface, and thus the addition of $F\Delta t$ water to the column, which is assumed to be mixed completely with the existing water in the upper layer, must be accompanied by the removal of that water after the mixing has taken place in order to maintain the same volume of water in the upper layer. An alternative expression would be required for a model with a free surface in which the upper layer of the model were able to change its volume.

These equations (1, 2) are used to update the values of temperature and salinity at the ocean surface.

For reasons of numerical stability, the salinity used in the derivation of the increments(S_o) is that at the earliest timestep of the leapfrog timestep (ie, if results are being calculated for

$t+\delta t$, S_0 is valid at $t-\delta t$). This is done immediately before the addition of solar heat flux.

Computational implementation

There is little complication in the implementation of the flux increments, except that unit conversion is required between the input fluxes (SI) and the model units (cgs).

```
   SUBROUTINE SFCADD  (TA,  QFLUX,  SFLUX,   SREF
   +                        IMT,  KM,  NT
   +                        DZ,  C2DTTS,  SPECIFIC _HEAT,  RHO_WATER
   +                        )
```

Define constants for array sizes

```
        INTEGER
   +,   IMT                 !  IN  Number of points in horizontal
   +,KM                     !  IN  Number of layers in the model
   +,   NT                  !  IN  Number of tracers
```

Physical arguments

```
        REAL
   +    TA(IMT,  KM,  NT)   !  INOUT  Tracer values
   +,   QFLUX  (IMT)        !  IN        Non-penetrating heat flux  (SI)
   +,   SFLUX   (IMT)       !  IN        Precip less evap  (SI)
   +,   SREF      (IMT)     !  IN        Reference salinity
   +,   DZ          (KM)    !  IN     Layer thickness   (cm)
   +,   C2DTTS              !  IN     Timestep     (S)
   +,   SPECIFIC HEAT       !  IN     Specific heat capacity  (SI)
   +,   RHO_WATER           !  IN     Density of sea water   (SI)
```

ANNEXE

UNIFIED MODEL DOCUMENTATION

OCEAN MODEL DOCUMENTATION

RIVER RUNOFF IN THE OCEAN MODEL

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Reviewer: T C Johns

DRAFT VERSION
14 February 1991

River Runoff in the Ocean Model

Introduction

The long-term behaviour of ocean circulation models has been shown to be sensitive to the net flux of fresh water at the surface, as this affects the surface salinity , which in turn affects the thermohaline circulation. Over the open ocean, the fresh water flux is given as the difference between precipitation and evaporation. At continental boundaries there is an additional contribution to this flux due to river outflow. This riverine flux has until now been included implicitly through a flux correction term (in which surface salinity is relaxed towards a reference value). This note describes the implementation of a simple scheme for the explicit representation of river outflow, which allows changes in river input to be modelled.

Implementation

River outflow is passed to the ocean model as a sparse ancillary field containing values of the fresh water fluxes in $Kg\ m^{-2} s^{-1}$ at river outflowpoints, and zeros elsewhere. The river runoff field is added to the net precipitation-minus-evaporation field to give the total fresh water flux:

F = PME + RR

where F is the total fresh water flux, and PME and RR are the contributions from net precipitation and river runoff respectively.

The total flux is then used to update the salinity in the topmost layer according to the description given in UM Documentation paper 50. i.e. if the salinities of the layer before and after adding in the flux are S and S , then

$$s_1 = s_0 \ (1 - F\Delta t \ / \rho\ o\Delta Z)$$

where ρ_o is a reference density, ΔZ is the layer depth, and Δt is the timestep.

The addition of the river outflow to just the surface layer (at present 10 metres thick) is consistent with observations of the Amazon outflow, which show the fresh water confined to the top 10m of the water column.

MODIFICATION OF SURFACE HEAT AND FRESH-WATER FLUXES TO ACCOUNT FOR DIFFERENCES BETWEEN MODELLED AND OBSERVED CLIMATOLOGIES

Author: S J Foreman
Reviewer: J O S Alves

Dated
14 September 1990

Modification of surface heat and fresh water fluxes to account for differences between modelled and observed climatologies

Introduction

When an ocean model is integrated using fluxes from climatological estimates or from an independent atmosphere model integration, the feedback loop between fluxes and sea surface temperature (SST) is broken. Thus, in the real world, an increase in SST might be expected to increase the evaporation from the surface of the ocean. Haney (1971) demonstrated how the feedback might be represented using a "pseudo air temperature" and a relaxation coefficient. The technique used in the Unified Model is derived from that of Haney.

Modification to surface fluxes

In the standard form of the model the deviations of SST from those used in the derivation of fluxes is taken into account by a relaxation term. This is applied to heat fluxes. An analogous modification is made to the fresh water flux (without physical justification) to ensure that the buoyancy is modified in a consistent manner.

The heat flux into the ocean varies with many meteorological variables: wind, cloud cover, and near-surface temperature and humidity being but a few. A coupled ocean-atmosphere model is able to calculate fluxes based on consistent variations of all these, but an ocean model has to make assumptions about the atmosphere's response to changes in SST. In the standard code used in ocean-only integrations of the ocean model it is assumed that all atmosphere variables remain unchanged. An alternative to this is to assume that the air-sea temperature difference is constant (eg Wells and King-Hele, 1985).

On the assumption that the heat flux depends only on variations of SST, then

$$Q_{new} = Q_{observed} + \delta Q / \delta T_{SST} \, (T_{model} - T_{observed}) \quad (1)$$

which may be written in the form

$$Q_{new} = Q_{observed} - \lambda \ (\ T_{model} - T_{observed} \ ) \qquad (2)$$

where λ is a pre-calculated relaxation coefficient. It is possible to estimate time and spatial variations of λ by differentiating the expressions for the sensible, latent, and longwave surface heat fluxes with respect to sea surface temperature. In the standard form of the Unified Model ocean code this is not done, and l is taken to be a constant which is specified externally and which has the same value at all points.
Fresh water fluxes are also modified in a manner similar to (2). The value of the relaxation coefficient (λ_s) is chosen to give the same timescale for relaxation of salinity as for temperature, The formula applied is, therefore,

$$F_{new} = F_{observed} - \lambda \ (S_{model} - S_{observed}) \qquad (3)$$

and

$$\lambda_s = - \lambda \ / \ (\ S_{observed} \ ) \qquad (4)$$

Programming considerations

The code is implemented in subroutine HNYCAL. This should be called before the heat and fresh water fluxes are used to modify the surface layer of the ocean. The routine updates the fluxes supplied to it, writing the new values back to the same location as the unmodified values.

```
      SUBROUTINE HNYCAL (T,
     +                                    HTN, PME ,  QFLUX, SFLUX,
     +                                    T_REF, S_REF,
     +                                     IMT,KM,NT,
     +                                    HANEY, SPECIFIC_HEAT,
     +                                    anom_heat, anom_salt
     +                                     )
```

Constants for array sizes

```
      INTEGER
     +    IMT              !     IN Number of points in horizontal
     +,   KM               !     IN Non penetrating heat flux  (W/m2)
     +,   NT               !     IN Number of tracers
```

Physical arguments

```
      REAL
     +    T  (IMT, KM, NT)     !    IN Tracer values
     +,      HTN  (IMT)        !    IN  Non penetrating heat flux  (W/m2)
     +,      PME  (IMT)        !    IN  Precip less evap  (Kg/m2/s )

     +,      QFLUX   (IMT)     !    OUT  Modified non- penetratinh heat flux
```

```
+,      SFLUX    (IMT)        !     OUT  Modified precip ;ess evap  (Kg/m2/s)
+,      T_REF     (IMT)       !     IN  Reference temperature
+,      S_REF     (IMT)       !     IN Refence salinity  (ppt less 35)
+,      HANEY                 !     IN  Relaxation as W/m2/s
+,      SPECIFIC HEAT         !     IN  Specific heat capacity
+,     anom_heat              !     OUT  Heating anomaly  (W/m2)
+,     anom_salt              !     OUT  P-E anomaly  (Kg/m2/s)
```

References

Haney, R.L 1971 Surface thermal boundary conditions for ocean circulation models

J. Phys. Oceanogr., 1, 241-248

Wells, N.C and S. King-Hele 1985 Parametrization of tropical ocean heat flux. Dept. Oceanography, Southampton University.