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DIAGNOSTICS ON PRESSURE LEVELS SUITABLE FOR CALCULATING EDDY FLUXES AND VARIANCES OF FIELDS

by

R. A. Stratton

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Climate Research
Meteorological Office
London Road
BRACKNELL
Berkshire
RG12 2SY
United Kingdom

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1. Introduction

This document describes some of the fields output from sections 15 and 16 of the Unified Model and their use when running in climate mode. It does not attempt to explain all the fields available from sections 15 and 16 as some of these are usually only requested if running in forecast mode. The fields described here can be used to derive quantities like the transient eddy kinetic energy and variances of selected fields without having to output the fields every timestep or day. This should mean less space is required for the output from a run and less computing time is required to calculate the quantities mentioned.

2. What is available and how is it calculated?

2.1 Section 15

The following fields of interest are available from section 15 of the Unified Model:

Item no.	PP code	Description
201	56	u component of velocity on pressure levels.
202	57	v component of velocity on pressure levels.
215	60	u*v on pressure levels.
216	16	T (temperature) on pressure levels on the wind grid.
217	11	u*T on pressure levels.
218	12	v*T on pressure levels.
219	13	T^2 on pressure levels.
220	58	u^2 on pressure levels.
221	59	v^2 on pressure levels.
222	40	ω (vertical velocity)on pressure levels.
223	14	ω*T on pressure levels.
224	53	ω*u on pressure levels.
225	54	ω*v on pressure levels.
226	95	q (specific humidity) on pressure levels.
227	46	q*u on pressure levels.
228	47	q*v on pressure levels.
235	1334	q*ω on pressure levels.
236	1335	1 if pressure surface above land 0 otherwise, on pressure levels.
237	63	Total kinetic energy per unit area. Integral over KE in each model layer.
238	1	Geopotential height, z, on pressure levels.
239		z*u on pressure levels.
240		z*v on pressure levels.
241	1399	mountain torque per unit area.
(242	40	ω^2 on pressure levels may be added in future.)

All the fields are output on the model wind grid points.

U, V, θ (potential temperature), and q are model variables, u and v being held on the wind grid and θ and q on the pressure grid. In this section of the model T and q on pressure levels on the wind grid are calculated by first interpolating from θ or q on model levels to T or q on the required pressure levels and then interpolating from the pressure grid to the wind grid using horizontal interpolation. The values of the model fields on pressure levels are derived by using the subroutine V_INT or V_INT_T in the case of temperature. All the product fields are calculated by using the individual fields already interpolated to the required pressure levels. This ensures that

the product field eg. u*v output from section 15 is identical calculating u*v from the u and v fields output separately from section 15. This fact is important when using the product fields to calculate variances and eddy diagnostics. Forming the product of u*v on model levels and then interpolating to the required pressure levels would not give the same answer and would invalidate its use in calculating other quantities.

Omega, vertical velocity is not a model variable and is recalculated in section 15 using an approximation to the full expression given in Unified Model documentation paper 10, the approximation replaces the variable radius of the earth r_s, used in the full expression, by a fixed value, a. This is not expected to alter the results except towards the top of the atmosphere.

In paper 10 the vertical velocity ω is given by

$$\omega_k = \left(\dot{\eta}\frac{\partial p}{\partial \eta} + u,\nabla p - \frac{\partial p}{\partial t} \right)_k \qquad (1)$$

where

$$\left(a\ \dot{\eta}\ \frac{\partial p}{\partial \eta} \right)_{k-1/2} = -\frac{\partial p}{\partial p_*} k + 1/2 \sum_{m=1}^{top} D_m + \sum_{m=k-1}^{top} D_m \qquad (2)$$

and

D_m is as defined paper 10 with r_s removed ie set to 1.

2.2 Section 16

Fields available from this section are;

Item No.	Description
202	Geopotential height on pressure levels
203	Temperature on pressure levels on the pressure grid.
224	Geopotential height^2 on pressure levels.

Note all the fields in this section are output on the pressure grid. The fields are calculated in a similar way to section 15 ie the model variable is interpolated to the required pressure level.

3. **Calculation of eddy diagnostics and variances**

In most climate runs many fields are requested as time averages, the averaging being done over all timesteps or over selected timesteps eg every midnight value.

For a field A it time averaged is defined as

$$\overline{A} = \frac{1}{n} \sum_{1}^{n} A_t$$

Transient of A

$$A_t' = A_t - \overline{A}$$

Variance of A

$$\overline{A'^2} = \frac{1}{n}\sum_{1}^{n} A_t^2 = (\Sigma A_t)^2 = \overline{A^2} - (\overline{A})^2$$

therefore this quantity can be calculated from the time average of A^2 and the time average of A, provided both are time averaged in the same way.
The transient eddy covariance of fields A and B is given by

$$\overline{A'B'} = \frac{1}{n}\sum_{1}^{n}(A - \overline{A})(B - \overline{B}) = \overline{AB} - (\overline{A})(\overline{B})$$

This can also be calculated by knowing the time average of A*B and the time averages of A and B.

Transient eddy kinetic energy is defined by

$$0.5(\overline{U'^2} + \overline{V'^2}) = 0.5(\overline{U}^2 + \overline{V}^2 - \{U\}^2 - \{V\}^2)$$

All the above quantities can now be calculated from a model run without having to ask for fields A and B at every timestep or day depending on how the time mean is to be calculated

4. Subroutine used

The following routines are involved in the calculation of diagnostics described here.

INITDIAG This routine is called once only at the being of a run. The routine does various checking to establish that the fields requested from sections 15 and 16 are on appropriate pressure levels. The routine then calls ST_DIAG1 and ST_DIAG2 to calculate any diagnostics requested on the first timestep.

ST_DIAG1 This routine calls DYN_DIAG. It extracts the list of required pressure levels for each diagnostic requested and passes this information into DYN_DIAG.

ST_DIAG2 This routine is similar to ST_DIAG1 but calls PHY_DIAG.

DYN_DIAG This routine calculates all the diagnostics requested from section 15.

OMEGA_DIAG This routine calculates the vertical velocity using the approximation mentioned earlier. It i s called from DYN_DIAG.

PHY_DIAG This routine calculates all the diagnostics requested from section 16 of the model.

ST_MEAN This routine is not actually required for the calculation of time means described here but is a routine which also calls DYN_DIAG and PHY_DIAG and therefore must be altered if changes are made to arguments passed to either of these routines.

The subroutines DYN_DIAG and PHY_DIAG call interpolation routines V_INT, V_INT_T, V_INT_Z and P_TO_UV. The methods used for interpolation by these subroutines are explained in the document S1.