ATMOSPHERIC ANGULAR MOMENTUM

EFFECTIVE ANGULAR MOMENTUM FUNCTION FOR EARTH ROTATION AND POLAR MOTION FROM THE UNITED STATES NMC ANALYSIS

AAM(AER) 87 * 01

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1. Introduction

Production of operational effective angular momentum functions (EAMF) has continued throughout 1988 from the global analysis of the United States National Meteorological Center (NMC). These functions, which relate the three components of Earth orientation to variations in winds (W) and atmospheric surface pressure (P), with and without the incorporation of the inverted barometer (IB) hypothesis, have been derived by Barnes et al. (1983). Their production from NMC analyses was described by Salstein (1987). Major changes of the NMC global analysis scheme during 1988 which may impact the EAMFs are highlighted in the next section : following that is a description of the data format.

2. NMC System Changes During 1988

The basic NMC global data assimilation system has been described by Dey and Morone (1985), although there have been a number of important modifications since. The changes in 1988 are summarized by the National Weather Service (1989). The major change in May represents an improvement in the surface evaporation which moistens the lowest layers of the atmosphere in the prediction model. A subsequent change implemented in November involves more realistic formulation of clouds. Because both these changes alter the atmosphere's heating and hence its circulation within the NMC model, they have the potential to impact the EAMF's though the magnitude of the impact is unknown.

Figure 1 is a plot of the angular momentum equivalent of the chi 3-wind term since 1981. One highlight in 1988 was a strong 30-50 day oscillation, especially during the early part of the year. Also during that year was a so-called "cold event" occurring in the tropical Pacific ocean (the opposite phase of the Southern Oscillation cycle to an El Niño event). The impact of the cold event on angular momentum in 1988 seems relatively small, unlike the markedly high values of momentum that occurred during the El Niño of 1982-83 and 1986-87.

3. Data Included

The EAMFs for the period January-December 1988 are given :

Date (MJD). chi 1-wind, chi 1 P 2/o IB, chi 1 P 2/ IB
Date (MJD), chi 2-wind, chi 2 P 2/o IB, chi 2 P 2/ IB
Date (MJD). chi 3-wind, chi 3 P 2/o IB, chi 3 P 2/ IB

Notes
1. Of the 732 twice-daily periods, 53 were missing, and are not on the file.
2. The chi 3 P w/o IB and chi 3 P w/ IB terms must be corrected by the addition of a relatively large constant, -13.980822, for precision.
3. All wind terms are integrated between 1 000 and 50mb.

References

Barnes,R.T., Hide,R., White,A.A., and Wilson,C.A. 1983: Atmospheric angular momentum fluctuations, length-of-day changes and polar motion. Proc.R.Soc. London,Ser.A.387 , pp.31-73.

Dey.C.H., Morone,L.L. 1985: Evolution of the National Meteorological Center global data assimilation system: January 1982 - December 1983, Mon.Wea.Rev., 113. pp.304-318.

National Weather Service, 1988: Annual NWP Progress Report . January 1989. Available from United States Department of Commerce, National Oceanic and Atmospheric Administration, National Weather Service, Washington, DC 20233.

Salstein,D.A. 1987: Operational production of effective angular momentum function for Earth rotation and polar motion. Annual Report of the BIH for 1987, pp.D-49-54.

AAM(AER) 87 * 01 Available from 1976 to 1988

Year	Number of meas.	Year	Number of meas.
1976	182	1982	630
1977	356	1983	656
1978	352	1984	679
1979	333	1985	686
1980	326	1986	696
1981	630	1987	722
		1988	679

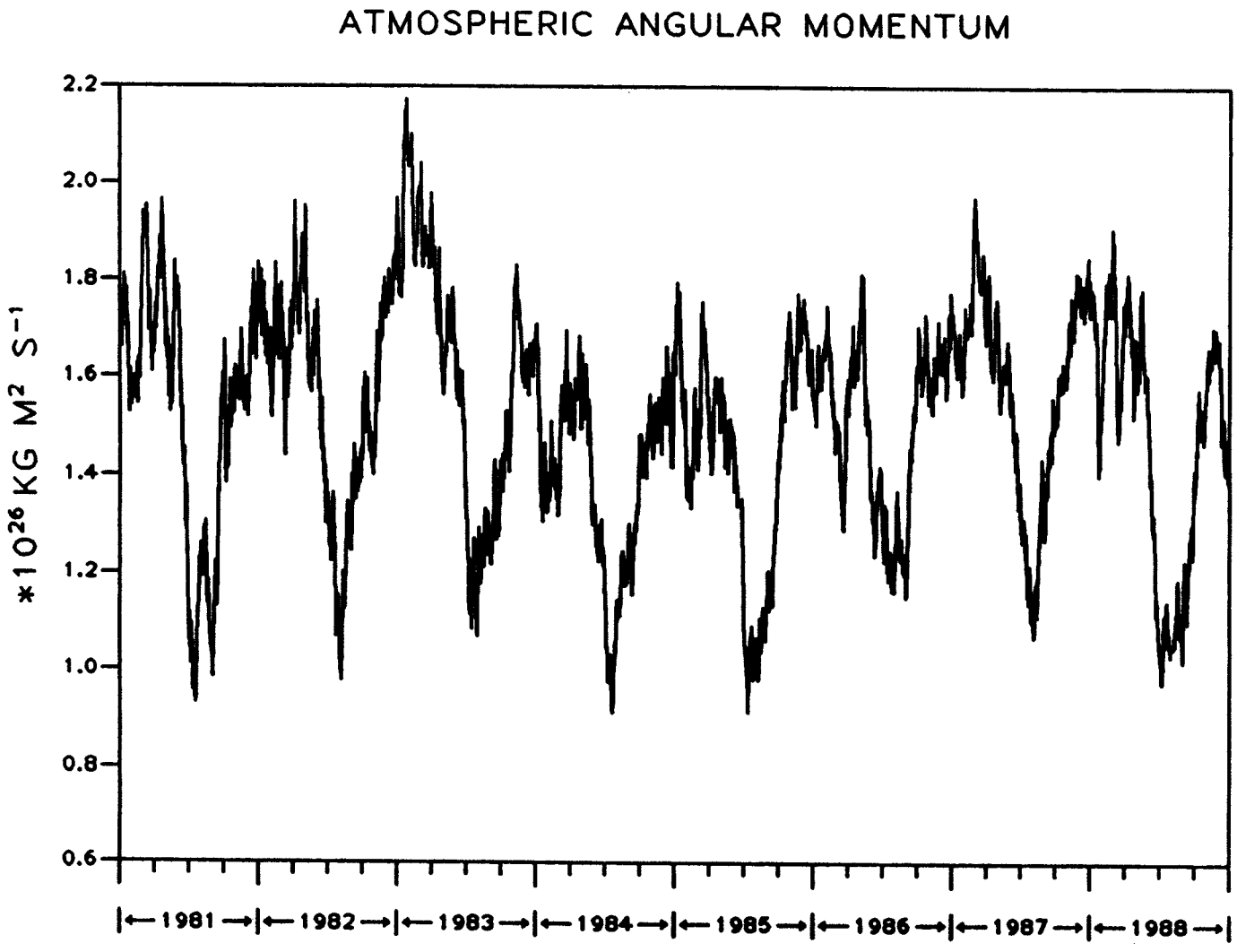

Fig. 1. Angular momentum of the atmosphere between 1000 and 50 mb during calendar years 1981-1988 based on the United States Meteorological Center (NMC) global analyses. Momentum units here can be derived from the chi 3-wind term on the data set through multiplication by the factor $-C\Omega$. C, the polar moment of intertia for the value 7.04×10^{37} kg m^2 and Ω, the earth's mean rotation frequency, is 7.29×10^{-5} s^{-1}.

EFFECTIVE ATMOSPHERIC ANGULAR MOMENTUM FUNCTIONS COMPUTED AT THE EUROPEAN CENTRE FOR MEDIUM-RANGE WEATHER FORECASTS

AAM(ECMWF) 87 * 01

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Since April 1987 the EAAM functions have been calculated operationally at ECMWF for all archived steps in the analysis-forecasting scheme, i.e. for analysis every 6 hours and for forecasts from 12 GMT each day up to 10 days ahead with an interval of 6 hours during the early forecasts after 5 days. The method used is described by Sakellarides (1989). Contributions to the three components of EAAM from wind (up to the 10 mb level) and from the surface pressure for both hemispheres are calculated and stored separately. These data have been extracted or re-calculated to make the time series for the following steps in the analysis-forecasting system easily available :

00 GMT analysis from 1 January 1988 onward,

12 GMT analysis from 1 January 1986 onward,

72, 120, and 240 hour forecasts from 1 January 1986 onward.

No calculations using the inverted barometer hypothesis have been done but these could be calculated from the available ECMWF archives.

References

G.Sakellarides, 1989 : Atmospheric effective angular momentum functions for 1986-1987. ECMWF Research Department Technical Report No.62.

AAM(ECMWF) 87 * 01 Available from 1986 to 1988

Year	Number of meas.
1986	365
1987	365
1988	732

EFFECTIVE ATMOSPHERIC ANGULAR MOMENTUM FUNCTIONS COMPUTED FROM THE JMA DATA

AAM(JMA) 89 * 01

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The effective atmospheric angular momentum (EAAM) functions proposed by Barnes Hide White & Wilson (1983) have been computed from the global analysis data provided by the Japan Meteorological Agency (JMA) since September 28. 1983. In general. the operational numerical weather prediction produces the three data sets called the analysis-phase analysis data. the initialized-phase analysis data and the predicted values. The JMA global analysis data are the analysis-phase analysis data. For the use of this file. it should be noticed that the results during 1983/12/1-1986/6/30 are once-a-day values computed from daily mean global data of the JMA global analysis data averaged at each grid and each level, otherwise twice-a-day(00GMT and 12GMT) values computed without averaging.

The JMA global analysis data have been made on 1.875-degree (2.5-degree before 1988/3/1) latitude-longitude grid system at sixteen levels (fifteen levels before 1988/3/1) up to ten millibars by the following analysis and forecast models. The analysis model is based on a multi-variate optimum interpolation method in troposhere and on a sinusoidal fitting method in stratosphere. with the initial guess of six hour forecast and the cut-off time of six hours after map time. The forecast model is based on a 1.875-degree (2.5-degree before 1988/3/1) and sixteen-level (twelve-level before 1988/3/1) global spectral model after a non-linear normal mode initialization with physics. The model has a horizontal resolution of triangular truncation at wavenumber 63 (42 before 1988/3/1) and incorpolates full physical processes. The details for the analysis and forecast models after 1988/3/1 can be found in Kitade (1988), and in Kashiwagi (1987) and Kanamitsu, Tada, Kudo, Sato & Isa (1983) for those before 1988/3/1.

For computing the EAAM functions, the sea level pressure, the geopotential height and the wind velocities at each lelvel are used. In addition, mountain heights of the same grid system are used for estimating surface pressures on land and for computing sea lelvel pressures on ocean with the Inverted Barometer hypothesis (IB). The surface pressures on mountains are computed from the geopotential heights by using a cubic spline interpolation technique with estimating the thickness temperatures by the same techniques. Vertical integrations of the wind terms of the EAAM functions are done from surface pressure on land (or the sea level pressure on ocean) to ten millibars. The integral formula to evaluate the EAAM functions are basically due to the equations (5.1), (5.2) and (5.3) of Barnes et al (1983), but the axial component of the EAAM functions is due to the equation (5.3) multiplied by -1 for convenience. No smoothing have been done after evaluation. Details of the evaluation can be found in Naito, Kikuchi and Yokoyama (1987).

Acknowledgements

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References

Barnes,R.T.H., R.Hide, A.A.White & C.A.Wilson, 1983 : Atmospheric angular momentum fluctuations, length-of-day changes and polar motion. Proc. R. Soc. Lond. A387, 31-73.

Kanamitsu,M., K.Tada, T.Kudo, N.Sato & S.Isa, 1983 : Description of the JMA operational spectral model, J. Meterol. Soc. Japan, 61, 812-828.

Kashiwagi,K..1987 : On the impact of space-based observing systems in the JMA global forecast/analysis system, J. Meteorol. Soc. Japan, 65, 189-220.

Kitade,T.,1988 : Numerical weather prediction in the Japan Meteorological Agency, JMA/NPD Technical Report. No.20.

Naito,I., N.Kikuchi & K. Yokoyama, 1987 : Results of estimating the effective atmospheric angular momentum functions based on the JMA global analysis data, Publ. Int. Latit. Obs. Mizusawa, 20, 1-11.

AAM(JMA) 87 * 01 Available from 1983 to 1988

Year	Number of meas.
1983	150
1984	357
1985	365
1986	549
1987	730
1988	732

EFFECTIVE ATMOSPHERIC ANGULAR MOMENTUM FUNCTIONS COMPUTED BY THE U.K. METEOROLOGICAL OFFICE USING DATA PROCESSED AT THE EUROPEAN CENTRE FOR MEDIUM-RANGE WEATHER FORECASTING

AAM(UKMOA)79 * 01

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Daily values of the effective atmospheric angular momentum (EAAM) functions defined by Barnes, Hide, White and Wilson (1983) have been calculated using meteorological fields produced by the European Centre for Medium-Range Weather Forecasting (ECMWF) since 01/12/1979. The wind integrals are approximated by the trapezoidal rule using initialised data interpolated onto 12 standard pressure levels between 1 000mb and 50mb. The matter terms are calculated using initiaalised surface pressure fields without applying the inverted barometer correction.

The present ECMWF operational model, which is documented by ECMWF Research Manuals 1-3 and also described by Simmons et al. (1989). Shaw et al. (1987) uses a 19 level hybrid (sigma/pressure) vertical grid and a spectral horizontal representation with triangular truncation at wavenumber 106. The model contains parametrisation schemes to represent sub-grid scale radiative and convetive processes. precipitation and boundary layer turbulence.

Data analyses are performed using a 3 dimensional multi-variate statistical interpolation scheme (for mass and wind fields). The first-guess field is a 6 hour forecast and the data cut-off time for the 12Z forecast is 20.45Z. A non-linear normal mode initialisation scheme is applied to the analysis fields to eliminate high frequency gravity waves.

Several improvements to the ECMWF operational model, which affect the matter terms particularly have been introduced since 1979. The representation of orography was changed on 01/04/1981 and 21/04/1983 and a schele for parametrising sub-grid scale gravity waves generated by topography included on 15/07/1986. Improvements in the initialisation of tropical diurnal variations were implemented on 04/03/86. The original gridpoint model was replaced by a T63 spectral model on 21/04/83 and the latter's resolution increased to T106 on 02/05/1985. The parametrisation of vertical diffusion was amended on 05/01/1988. Details of other changes are recorded in the quarterly ECMWF Forecast Reports.

Data is missing from the series on only two days - 31 Mar.1984 and 26 Aug.1987. The times of validity of the data are tabulated below.

Period	Hour of validity
01/12/79 - 30/11/80	12Z
01/12/80 - 15/03/82	00Z
16/03/82 - 29/02/84	12Z
01/03/84 - 15/03/84	00Z
15/03/84 - 31/05/87	12Z
01/06/87 - 31/12/88	mean of 00Z 06Z 12Z and 18Z

IERS(1989) Technical Note no 2.

References

Barnes R.T.H. Hide R. White.A.A. and Wilson.C.A. 1983 Atmospheric angular momentum fluctuations. length of day changes, and polar motion. Proceedings of the Royal Society A 397, pp.31-73.

ECMWF Research Manual 1 1986 ECMWF data assimilation scientific documentation. eds. Lonneberg,P. and Shaw,P.

ECMWF Research Manual 2 1986 ECMWF forecast model adiabatic part. ed.J.F.Louis.

ECMWF Research Manual 3 1986 ECMWF forecast model physical parametrisation. ed. J.F. Louis.

ECMWF Forecast Reports (issued quarterly by the ECMWF).

Shaw,D.B., Lonneberg,P., Hollingsworth,A., and Unden,P. 1987:Data assimilation: The 1984/85 revisions of the ECMWF mass and wind analysis. Quart.J.Roy.Meteor Soc. .113. pp.533-566

Simmons,A.J., Burridge,D.M., Jarraud,M., Girard,C. and Wergen,W. 1989: The

ECMWF medium range prediction models: Development of the numerical formulations and the impact of increased resolution. Met.and Atmos.Phys. (in the press).

AAM(UKMOA) 79 * 01 Available from 1979 to 1988

Year	Number of meas.	Year	Number of meas.
1979	31	1984	366
1980	366	1985	365
1981	365	1986	365
1982	365	1987	364
1983	365	1988	366

EFFECTIVE ATMOSPHERIC ANGULAR MOMENTUM FUNCTIONS COMPUTED BY THE U.K. METEOROLOGICAL OFFICE USING DATA PROCESSED AT THE U.K. METEOROLOGICAL OFFICE

AAM(UKMOB) 83 * 01

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Daily values of the effective atmospheric angular momentum (EAAM) functions defined by Barnes. Hide, White and Wilson (1983) have been calculated using meteorological fields produced by the United Kingdom Met.Office (UKMO) since 01/05/1983. The matter terms are evaluated without applying the inverted barometer correction.

From 01/05/1983 to 30/10/1986 the wind terms were determined from "analysis" data at 15 standard pressure levels between 1 000mb and 20mb and the matter terms from surface pressure fields reconstructed from the mean sea level pressure and a topographic data set. From 1/11/1986 to 26/11/1986 the wind integrals extended from 950mb to 50mb and the matter terms were calculated using surface pressure fields. As from 27/11/1987 the wind terms have been evaluated using data on all the model's 15 sigma levels §which extend up to about 25mb) and the matter terms have been found from the model's surface pressure field.

The present global UKMO operational model, which is described by Bell Dickinson (1987) uses a 15 level sigma coordinate vertical grid which extends up to about 25mb and a horizontal grid with 192 points around each latitude circle and 121 rows from north to south pole. The model contains parametrisation schemes to represent sub-grid scale radiative and convective processes, precipitation and boundary layer turbulence.

Data are assimilated into the numerical model by adding to the wind and the pressure fields a proportion of interpolated observational increments at each timestep during the 6 hour period preceding the analysis time. Gravity wave noise is reduced by damping horizontal divergence during this period.

The main change to the global UKMO model since 01/05/1983 has been the introduction of a scheme for parametrising the momentum transports due to sub grid scale mountain gravity waves on 12/12/1984. Details of recent changes are recorded in each "Quarterly report on numerical products from Bracknell".

Until 30/10/86 all the data is valid at 00Z. From 01/11/87 data is available for both 00Z and 12Z. Data is missing at the following time :

00Z on 27/05/83, 31/05/83, 11/06/83, 12/09/83, 03/12/86, 19/02/87, 23/03/87, 07/09/87, 22/09/87, 16/10/87, 26/03/88, 22/04/88, 05/05/88, 14/10/88 :

12Z on 02/12/86, 18/02/87, 19/02/87, 06/09/87, 21/09/87, 03/11/87, 01/12/87, 26/03/88. 01/07/88, 03/12/88.

References

Barnes.R.T.H.. Hide R.. White.A.A.. and Wilson.C.A. 1983: Atmospheric angular momentum fluctuations, length-of-day changes, and polar motion. Proceedings of the Royal Society A . 387. pp.31-73.

Bel,R.S., and Dickinson,A. 1987: London Meteotological Office Scientific Paper No.41 . The Meteorological Office operational numerical weather prediction system. U.K. Meteorological Office, London.

Quarterly report on numerical products from Bracknell . U.K. Meteorological Office, London.

AAM(UKMOB) 83 * 01 Available from 1983 to 1988

Year	Number of meas.
1983	241
1984	366
1985	365
1986	306
1987	721
1988	725