The Meridional Eddy Transport of Kinetic Energy at 500 Mb

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The meridional transport of kinetic energy across latitude ϕ per unit time and per unit pressure difference is given by

$$T_k(\phi, p, t) = \frac{2\pi a \cos\phi}{g}\left[v\left(\frac{u^2+v^2}{2}\right)\right], \qquad (1)$$

where u is the zonal wind speed, v is the meridional wind speed, a is the radius of the earth, g is the acceleration of gravity and the brackets denote an average with respect to longitude, (cf., STARR 1948, and KAO 1954). If we let $x' \equiv x - [x]$, T_k can be resolved into components as follows:

$$T_k = T_{ko} + T_{k1} + T_{k2} \qquad (2)$$

$$T_{ko} = \frac{2\pi a \cos\phi}{g}[v]\left(\frac{[u^2]+[v^2]}{2} + [v'^2]\right)$$

$$T_{k1} = \frac{2\pi a \cos\phi}{g}[u]\,[u'v']$$

$$T_{k2} = \frac{2\pi a \cos\phi}{g}\left[v'\left(\frac{u'^2+v'^2}{2}\right)\right]$$

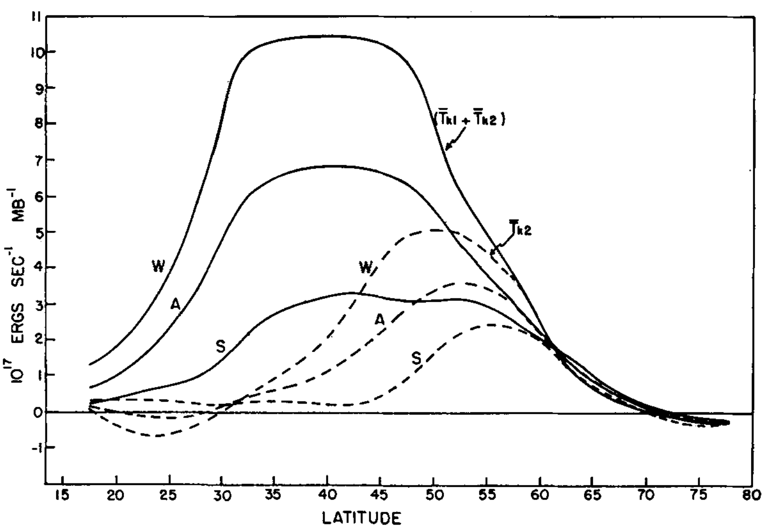

Fig. 1. Average rate of poleward eddy transport of kinetic energy at 500 mb. The solid line denotes $(\overline{T}_{k1} + \overline{T}_{k2})$ and the dashed line $\overline{T}_{k2}$, the difference being $\overline{T}_{k1}$. W, S, and A denote the winter, summer, and annual averages, respectively.

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Table 1. Average rate of northward eddy transport of kinetic energy at 500 mb. A bar denotes the average and $S(x) \equiv \pm 2(\overline{x^2} - \overline{x}^2)^{1/2} M^{-1/2}$ the error of the average. M is the number of independent data, which we have taken to be half the number of days, N. Units are 10^{15} ergs sec^{-1}mb^{-1}. Graphical representation is given in Figure 1.

	ϕ (N)	17.5	22.5	27.5	32.5	37.5	42.5	47.5	52.5	57.5	62.5	67.5	72.5	77.5
$(\overline{T}_{k1} + \overline{T}_{k2})$	annual (365)	74	160	333	605	669	684	635	463	314	148	40	−10	−27
	winter (181)	26	263	578	998	1,039	1,043	968	608	382	133	31	−5	−17
	summer (184)	22	59	91	218	304	331	307	321	247	163	49	−15	−37
$S(T_{k1} + T_{k2})$	annual......	38	55	83	204	161	168	171	163	144	112	68	52	32
	winter	59	100	147	390	287	300	307	286	259	200	116	86	52
	summer.....	30	31	40	72	96	115	122	154	130	100	71	58	38
$\overline{T}_{k2}$	annual......	17	−10	−7	39	84	160	294	358	305	143	54	−16	−27
	winter	7	−58	−34	51	142	299	493	503	374	133	41	−18	−18
	summer.....	28	36	19	27	26	23	96	216	238	153	67	−13	−35
$S(T_{k2})$	annual......	27	31	42	81	103	126	130	140	129	93	55	40	28
	winter	44	54	81	158	196	233	240	250	232	167	90	66	45
	summer.....	30	31	25	42	62	88	89	119	113	88	61	42	33

Since $[v]$ cannot be estimated reliably with existing wind data it is not feasible to measure T_{k0}. T_{k1} and T_{k2} can be measured with some confidence using geostrophic winds. The results of such measurements, based on hemispheric 500 mb data for each day of 1951, are summarized in Table 1 and Figure 1 in the form of averages for the entire year, the winter half-year (November to April) and the summer half-year (May to October). The average meridional convergence of kinetic energy, $C_k = \partial T_k / \partial \phi$, is given in Table 2 and Figure 2.

Since T_k is a cubic function of the wind we should expect that measurements at 500 mb,

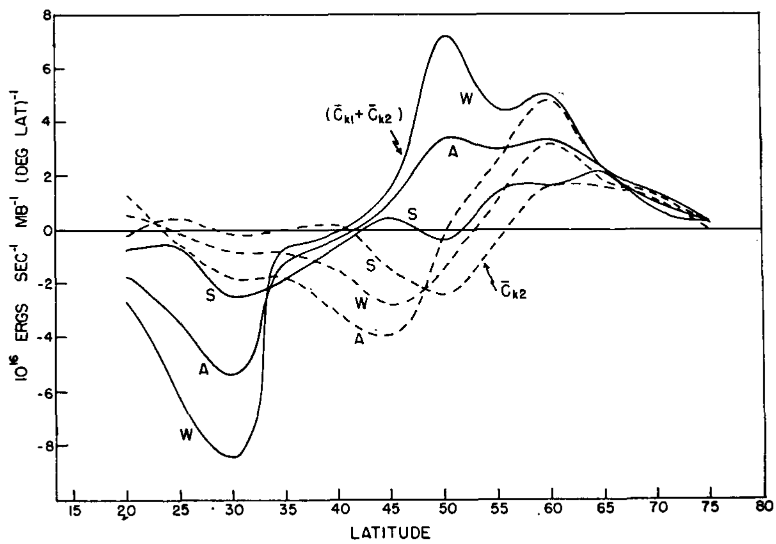

Fig. 2. Average convergencey of kinetic energy at 500 mb. The solid line denotes $(\overline{C}_{k1} + \overline{C}_{k2})$ and the dashed line $\overline{C}_{k2}$, the difference being C_{k1}. W, S, and A denote the winter, summer, and annual averages, respectively.

Table 2. Average meridional convergence of kinetic energy, $\overline{C}_k = \partial \overline{T}_k / \partial \phi$. Units are 10^{15} ergs sec^{-1} mb^{-1} deg. lat^{-1}. Graphical representation is given in Figure 2.

		20	25	30	35	40	45	50	55	60	65	70	75
	annual........	−17	−35	−54	−13	−3	+10	+34	+30	+33	+22	+10	+4
$(\overline{C}_{k1} + \overline{C}_{k2})$	winter........	−27	−63	−84	−8	−1	+15	+72	+45	+50	+21	+13	+3
	summer.......	−7	−6	−25	−17	−5	+5	−3	+15	+17	+23	+7	+5
	annual........	+6	−1	−9	−9	−15	−27	−13	+11	+32	+18	+14	+2
$\overline{C}_{k2}$	winter........	+13	−5	−17	−18	−31	−39	−2	+26	+48	+19	+12	0
	summer.......	= 2	+4	−2	0	+1	−15	−24	−5	+17	+17	+16	+4

where the wind speeds are somewhat less than at jet stream levels, underestimate the average over the entire depth of the atmosphere This is in agreement with the results reported by MINTZ (1955), PISHAROTY (1955) and PALMÉN, RIEHL and VUORELA (1958), who discuss multilevel geostrophic computations of $(T_{k1} + T_{k2})$ for a four month period.

The transports of kinetic energy can be viewed as manifestations of the non-linear processes whereby energy is exchanged between harmonic components of the flow (cf., SALTZMAN and FLEISHER 1960). In lower latitudes transports involving interactions between the mean zonal current and the eddies, as measured by T_{k1}, are more effective than those involving the interactions between the eddies, as measured by T_{k2}. The reverse is true in higher latitudes.

The largest transports occur between 30° N and 50° N, leading to an average convergence of kinetic energy into the polar cap north of 40° N of the order of 10^{18} ergs sec^{-1} mb^{-1}. This is the same as the order of the eddy generation of kinetic energy within the cap measured by $\int_{\phi=40°}^{\phi=90°} \frac{2\pi a^2 \cos\phi}{g} [\omega'\alpha'] \, d\phi$ ($\omega = dp/dt$, and α = specific volume: see WHITE and SALTZMAN 1956, SALTZMAN and FLEISHER 1959, and WIIN-NIELSEN 1959).

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