Scott, R. K.; **Tissier, A.-S.**

The generation of zonal jets by large-scale mixing. (English) Zbl 1309.76107

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Summary: The development of zonal flows on a midlatitude β-plane subject to a time-varying topographic forcing is investigated in a series of numerical integrations in which the forcing is concentrated at large scales, and in which the usual two-dimensional inverse energy cascade is absent. In contrast to the case of small-scale forcing, where mixing of potential vorticity occurs largely through the action of small-scale eddies, mixing of potential vorticity in this case occurs predominantly in latitudinally localized Rossby wave critical layer regions, whose width grows continuously in time due to the entrainment of background fluid. The potential vorticity is found to organize into a piecewise constant staircase-like profile, monotonic in latitude, provided the ratio $L_{\mathrm{Rh}}/L_f \gtrsim 1$, where L_{Rh} is the usual Rhines scale and L_f is the scale of the forcing; this may be regarded as supplemental to the condition $L_{\mathrm{Rh}}/L_\epsilon \gtrsim 6$, where $L_\epsilon = (\epsilon/\beta^3)^{1/5}$ and ϵ is the rate of energy input, obtained recently [*R. K. Scott* and *D. G. Dritschel*, J. Fluid Mech. 711, 576–598 (2012; Zbl 1275.76132)] for the case of small-scale forcing. The numerical results further suggest that the nature of the potential vorticity mixing is controlled by the ratio L_ϵ/L_f, and occurs predominantly in critical layers when $L_\epsilon/L_f \lesssim 1/6$. A combined condition for staircase formation may therefore be expressed as $L_{\mathrm{Rh}}/L_\epsilon \gtrsim \max\{6, L_f/L_\epsilon\}$. Finally, in a separate set of experiments it is shown that when forcing is represented by an additive source term in the evolution equation, as is common practice in numerical investigations of two-dimensional turbulence, the effect of non-conservation of potential vorticity may obscure the development of the staircase profile in the critical layer mixing dominated regime.

MSC:

76F25 Turbulent transport, mixing
76B10 Jets and cavities, cavitation, free-streamline theory, water-entry problems, airfoil and hydrofoil theory, sloshing

Full Text: DOI

References:

[1] DOI: 10.1098/rsta.1915.0001 · doi:10.1098/rsta.1915.0001
[2] DOI: 10.1002/qj.49709239302 · doi:10.1002/qj.49709239302
[3] DOI: 10.5194/adgeo-15-47-2008 · doi:10.5194/adgeo-15-47-2008
[4] DOI: 10.1175/2007JAS2223.1 · doi:10.1175/2007JAS2223.1
[5] DOI: 10.1017/S0022112008000153 · Zbl 1151.76617 · doi:10.1017/S0022112008000153
[6] DOI: 10.1175/JAS4000.1 · doi:10.1175/JAS4000.1
[7] DOI: 10.1017/S0022112075001504 · Zbl 0366.76043 · doi:10.1017/S0022112075001504
[8] DOI: 10.1175/1520-0469(1978)035<1399:PCBROJ>2.0.CO;2 · doi:10.1175/1520-0469(1978)035<1399:PCBROJ>2.0.CO;2
[9] DOI: 10.1017/jfm.2012.410 · Zbl 1275.76132 · doi:10.1017/jfm.2012.410
[10] DOI: 10.1175/2007JAS2227.1 · doi:10.1175/2007JAS2227.1
[11] DOI: 10.1017/S0022112091002720 · doi:10.1017/S0022112091002720
[12] DOI: 10.1017/CBO9780511790447 · doi:10.1017/CBO9780511790447
[13] DOI: 10.1175/JAS4013.1 · doi:10.1175/JAS4013.1
[14] DOI: 10.1175/1520-0469(1998)055<0611:TDTAPZ>2.0.CO;2 · doi:10.1175/1520-0469(1998)055<0611:TDTAPZ>2.0.CO;2
[15] DOI: 10.1063/1.1752928 · Zbl 1186.76124 · doi:10.1063/1.1752928
[16] DOI: 10.1175/JAS4003.1 · doi:10.1175/JAS4003.1
[17] McIntyre M. E., J. Meteorol. Soc. Jpn. 60 pp 37– (1982) · doi:10.2151/jmsj1965.60.1_37
[18] DOI: 10.1038/328590a0 · doi:10.1038/328590a0

[19] DOI: 10.1175/1520-0469(1995)052%3c1288:OTSEOT%3e2.0.CO;2 · doi:10.1175/1520-0469(1995)052<1288:OTSEOT>2.0.CO;2

[20] DOI: 10.1007/s00332-006-0800-3 · Zbl 1370.76015 · doi:10.1007/s00332-006-0800-3

[21] DOI: 10.1175/1520-0469(1994)051<0654:BRWIAM>2.0.CO;2 · doi:10.1175/1520-0469(1994)051<0654:BRWIAM>2.0.CO;2

[22] DOI: 10.1175/1520-0469(1994)051<0530:CAWSAT>2.0.CO;2 · doi:10.1175/1520-0469(1994)051<0530:CAWSAT>2.0.CO;2

[23] DOI: 10.1175/1520-0469(2002)059%3c2347:WBAMAT%3e2.0.CO;2 · doi:10.1175/1520-0469(2002)059<2347:WBAMAT>2.0.CO;2

[24] DOI: 10.1175/JAS4008.1 · doi:10.1175/JAS4008.1