Rueda, Francisco J.; **Sanmiguel-Rojas, Enrique**; **Hodges, Ben R.**

Baroclinic stability for a family of two-level, semi-implicit numerical methods for the 3D shallow water equations. (English) Zbl 1287.76172

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Summary: The baroclinic stability of a family of two time-level, semi-implicit schemes for the 3D hydrostatic, Boussinesq Navier-Stokes equations (i.e. the shallow water equations), which originate from the TRIM model of *V. Casulli* and *R. T. Cheng* [Int. J. Numer. Methods Fluids 15, No. 6, 629–648 (1992; Zbl 0762.76068)], is examined in a simple 2D horizontal-vertical domain. It is demonstrated that existing mass-conservative low-dissipation semi-implicit methods, which are unconditionally stable in the inviscid limit for barotropic flows, are unstable in the same limit for baroclinic flows. Such methods can be made baroclinically stable when the integrated continuity equation is discretized with a barotropically dissipative backwards Euler scheme. A general family of two-step predictor-corrector schemes is proposed that have better theoretical characteristics than existing single-step schemes.

MSC:

76M12 Finite volume methods applied to problems in fluid mechanics
76E20 Stability and instability of geophysical and astrophysical flows
86A05 Hydrology, hydrography, oceanography

Keywords:

inviscid limit; barotropically dissipative Euler scheme; two-step predictor-corrector scheme

Software:

TRIM

Full Text: DOI

References:

[1] Casulli, International Journal for Numerical Methods in Fluids 15 pp 629– (1992)
[2] Appt, Limnology and Oceanography 49 pp 919– (2004)
[3] Shchepetkin, Ocean Modelling 9 pp 347– (2005)
[4] Yuan, International Journal for Numerical Methods in Fluids 44 pp 811– (2004)
[5] . A description of a three-dimensional coastal ocean circulation model. In Three-dimensional Coastal Ocean Models, (ed.). American Geophysical Union: Washington, DC, 1987; 1–16.· doi:10.1029/CO004p0001
[6] Griffies, Ocean Modelling 2 pp 123– (2000)
[7] Campin, Ocean Modelling 6 pp 221– (2004)
[8] Rueda, Limnology and Oceanography 50 pp 1638– (2005)
[9] Zaker, Journal of Coastal Research 18 pp 470– (2002)
[10] Casulli, Computers and Mathematics with Applications 27 pp 99– (1994)
[11] Casulli, Journal of Hydraulic Engineering 124 pp 678– (1998)
[12] Casulli, International Journal for Numerical Methods in Fluids 30 pp 425– (1999)
[13] Casulli, International Journal for Numerical Methods in Fluids 32 pp 331– (2000)
[14] Ahsan, Journal of Hydraulic Engineering 125 pp 912– (1999)
[15] Hodges, Limnology and Oceanography 45 pp 1603– (2000)
[16] Rueda, Journal of Geophysical Research–Oceans 108 (2003)· doi:10.1029/2001JC000942
[17] Chen, Journal of Computational Physics 189 pp 557– (2003)
[18] Hodges, Journal of Engineering Mechanics 130 pp 904– (2004)
[19] Gross, International Journal for Numerical Methods in Fluids 28 pp 157– (1998)
[20] Robson, Ecological Modelling 174 pp 203– (2004)

[21] Laval, Limnology and Oceanography 48 pp 983– (2003)

[22] Gross, Journal of Hydraulic Engineering 125 pp 1199– (1999)

[23] Eliason, International Journal for Numerical Methods in Fluids 24 pp 771– (1997)

[24] . Numerical Modeling of Ocean Dynamics. World Scientific: Singapore, 1993; 480.· doi:10.1142/1970

[25] Gross, International Journal for Numerical Methods in Fluids 38 pp 307– (2002)

[26] Gray, Advances in Water Resources 1 pp 83– (1977)

[27] Aspects of a computational model for long period water-wave propagation. Rand Memorandum RM-5294-PR, Santa Monica, 1967.

[28] Introduction to Geophysical Fluid Dynamics. Prentice-Hall: Englewood Cliffs, NJ, 1994; 320.

[29] Hodges, Ocean Modelling 13 pp 44– (2006)

[30] Laval, Journal of Hydraulic Engineering 129 pp 215– (2003)

[31] Leonard, Computer Methods in Applied Mechanics and Engineering 19 pp 59– (1979)

[32] . Linear accuracy and stability of semi-implicit two-level predictor-corrector methods for hydrostatic barotropic/baroclinic flows. International Journal for Numerical Methods in Fluids 2006, submitted for publication.

[33] Camassa, Physica D 60 pp 1– (1992)