Geophysical Research Abstracts,
Vol. 10, EGU2008-A-01933, 2008
SRef-ID: 1607-7962/gra/EGU2008-A-01933
EGU General Assembly 2008

Upstream non-oscillatory advection schemes on irregular grid

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Advection is a fundamental physical process associated with many fluid applications, such as mass, energy, and tracer transportation in the atmosphere. Many advection schemes are, however, plagued with numerical oscillations. A great deal of effort has been spent on suppressing these spurious oscillations and leads to inventions of many novel techniques and schemes, such as the flux corrected transport algorithm and assorted flux limiters. Most of these advanced schemes result in increased computing cost and complicated algorithm. It is not a surprise that advection is one of the most expensive processes in many numerical models. Although computing power has increased dramatically in the last few decades, demands for higher resolution, more physics and even coupled models have far outstripped the computer advance. It is hence still desirable to develop fast and robust advection schemes. Two Upstream Non-Oscillatory advection schemes of 2nd- (UNO2) and 3rd- (UNO3) order accuracy are derived by combining existing advection schemes in different monotonic regions. UNO2 is an extension of the MINMOD scheme by removing the gradient sign comparison. UNO3 follows the ULTIMATE QUICKEST scheme to use the well-known 3rd-order (in both space and time) scheme in its central part but replaces the flux limiters in the rest monotonic regions with a doubled MINMOD scheme. Outside the monotonic region UNO3 reverts to the first-order upstream scheme as other non-oscillatory advection schemes. Both schemes are based on local gradients and expressed in flux form for easy implementation on irregular grid. An advective-conservative hybrid operator is used to extend these schemes to multi-dimensions. Classical numerical (1-D constant speed and 2-D solid rotation and deformation) tests have demonstrated that these schemes are non-oscillatory, conservative, shape-

preserving and faster than their classical counterparts without losing accuracy.