# Locally isotropic and slightly anisotropic description of the scale-by-scale scalar transport

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The behaviour of a scalar (kinetic energy, scalar variance etc.) at a given scale in turbulent flow depends upon the advecting field, the molecular effects and large-scale effects (decay, mean shear, mean scalar gradient etc). The simplest exact way to describe statistical properties at any scale is to study the second-order moments, which naturally involves the third-order moments of the scalar. This was first developed by A.M. Yaglom [1] and further extended for the turbulent kinetic energy [2] under the ideal assumption of local isotropy. However, for moderate Reynolds numbers of slightly heated grid turbulence, Yaglom's equation is only valid for a restricted range of scales, notwithstanding the approximate validity of local isotropy in this flow. This range increases with increasing Reynolds numbers, e.g. [3]. Clearly, it is important to identify and quantify the terms that allow the energy balance to be closed, in order to better understand all the physical phenomena brought into play in a flow/region of a flow. In order to proceed, several methodologies are possible. They are outlined below in increasing order of difficulty:

1) When local isotropy holds, large-scale effects are to be taken into account: e.g. the large-scale inhomogeneity in grid turbulence in which the scalar is introduced by a mandoline [3]; the decay and production effects on the axis of a round jet ([4] and references herein). For a passive scalar injected by a mean scalar gradient, it was proven [5] that the large-scale effects are present and satisfactorily improve the balance over a significant range of (intermediate to large) scales, although at the smallest ones the balance is not satisfactorily closed, most likely due to local isotropy being violated in such mixing.
2) Therefore, in flows where local isotropy is not appropriate, different approaches should be considered. This paper only considers axisymmetrical flows, and cylindrical coordinates are naturally used.
    a) One way is to follow the increments calculated over space separations in a plane perpendicular to the axisymmetry axis. The limiting form for small separations of this equation reduces to the 2-D definition of the scalar dissipation rate, which is verified exactly.
    b) A second approach is to consider increments along any spatial direction, which could be decomposed along spatial directions either parallel or perpendicular to the symmetry axis [6], [7]. The slight anisotropy is considered via the spherical harmonics expansion e.g. [8], for both the second-and-third-order scalar structure functions. The resulting scale-by-scale energy balance equation is tested against experimental data obtained by PLIF (Planar Laser Induced Fluorescence) for scalars [9], and by PIV for the velocity field and its kinetic energy, in either decaying grid turbulence (at very large scales), in a single round jet or multiple opposed/sheared jets.

All the analytical developments are discussed in the context of the scalar transport, for axisymmetric and slightly anisotropic conditions (only the low order contributions in the spherical harmonics expansion are kept); the exact tensorial representation of the axisymmetric field [6] being beyond the scope of this contribution.

## Bibliography:

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