Turbulent dispersion analysis via distance-neighbor graphs inside a top cloud boundary in temporal decay

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We expand on the original studies on atmospheric diffusion shown on a distance neighbour graph, Q, by Lewis F. Richardson(1926)[1], a quantity that effectively defines a distribution of particles over a separation distance, ℓ. Because of its definition we expect Q to evolve according to an equation of type $\partial Q/\partial t = \partial/\partial l\,(F(l)\partial Q \partial l)$. Particular emphasis was put on the search for a correct form of the diffusion function F. Richardson originally proposed an $F \sim l^{4/3}$ law. His studies have then been revisited by many, among which Obukhov[2,3], leading to the so-called Richardson-Obukhov $l^2 \sim t^3$ theory, which holds in the homogeneous, isotropic turbulence regime. Our analysis is carried out on direct numerical simulations (DNS) of a time-decaying turbulent shearfree layer which represents a small portion of a top warm cloud boundary, a multiphase simulation where air, water vapor and water drops have been included[4,5]. In the interfacial region between the cloud and the surrounding clear-air, we expect F to contain factors that carry information peculiarly linked to the high **anisotropy** and **small scale intermittency** there observed. Here are two possible scaling laws that give values whose order is in good agreement with those originally reported by Richardson in the collection of data from Earth Boundary Layers observations (page 724[1]: Schmidt 197, Akerblom 1908, Taylor 1914, Hesselberg and Swerdrup 1915): $F(l,t) \sim \epsilon^{2/3}(t)\langle\kappa_s(t)\rangle\tau_p l^{2/3}$ and $F(l,t) \sim \epsilon^{2/5}(t)\langle\kappa_s(t)\rangle\tau_p^{1/5} l^{6/5}$. Where, τ_p is the phase relaxation time, κ_s is the supersaturation kurtosis and $\epsilon(t)$ is the energy dissipation rate. The variation ranges of these quantities in the observed temporal window, $t/\tau_0 \in 1 \div 6$, are the following: $\epsilon(t) \in 100 \div 10$ cm^2/s^3; $\langle\kappa_s(t)\rangle = 3$ in the cloud and $\in 30 \div 15$ in the mixing; $\tau_p(t) \sim 10$ in the cloud and $\in 20 \div 80$ in the mixing. The figure below show the computed two turbulent diffusion trends and the large diffusion increase in the mixing region. A broader analysis will be presented during the oral communication.

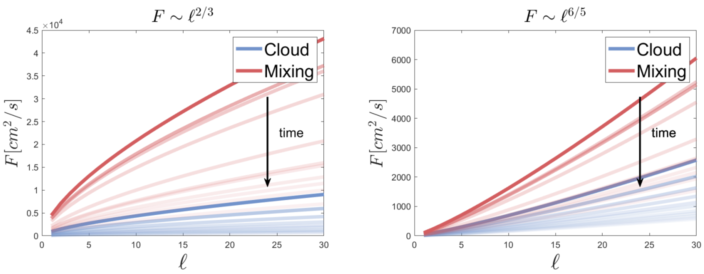

Figure 1: The transparency level shows the time decay. The interfacial cloud boundary is an instance of anisotropic shearless turbulence where transport and intermittency are particularly intense

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[2] Sawford, *Ann. Rev. Fluid Mech.* **33**, 289 (2001).
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[5] Fossà et al., *Physics of fluids* **34**, (2022).