Turbulence measurements from UAV and from meteorological balloons: a comparison

R. Wilson[(1)], Hashiguchi H.[(2)], Kantha L.[(3)], Laurence D.[(3)], Mixa T.[(3)], Yabuki M.[(2)], Luce H.[(4)] and Tsuda T.[(2)]

(1) LATMOS, Université Pierre et Marie Curie (UPMC), Paris, France
(2) Research Institute for Sustainable Humanosphere, Kyoto University, Kyoto, Japan
(3) Department of Aerospace Engineering, University of Colorado, Boulder, CO, USA
(4) MIO, Université de Toulon, France.

The Shigaraki UAV-Radar Experiment (ShUREX) is an international (US-Japan-France) observational campaign dedicated to the study of the small scale dynamics of the lower troposphere. The observations were performed by unmanned aerial vehicles (UAV), by the MU (Middle and Upper atmosphere) radar, by lidars and by meteorological balloons. Two campaigns were conducted in 2015 and 2016 at the Shigaraki MU Observatory, Japan. The 2015 campaign lasted for two weeks (June 1st to June 14th) and the 2016 campaign lasted for three weeks (May 26th to June 14th).
The UAV DataHawk was developed by the University of Colorado, Boulder. It was equipped with fast response temperature sensor (coldwire) and velocity sensor (Pitot tube) as well as with an IMET radiosonde. UAVs were flown near and over the MU radar to obtain measurements in the atmospheric column in the immediate vicinity of the radar. Continuous operation of the radar in range imaging mode enabled fine-scale structures to be visualized. It also permitted the UAV to be commanded to sample interesting structures, guided in near real time by the radar images. During several UAV flights, standard meteorological balloon were also launched.
The ShUREX campaign permitted for the very first time, to evaluate the consistency of turbulence measurements from various observational means. Dynamics parameters such as turbulent kinetic energy or dissipation rates of variances (temperature or velocity) can be estimated directly from the fast temperature and velocity sensors of the UAV. These parameters can be independently inferred either from the the backscattered radar signal or from the raw data of radiosondes. The consistency of the radar and UAV estimates will be presented elsewhere. The present work focuses on the comparison of turbulence estimates from balloon data, or by combining radar and balloon data, with UAV estimates.
In recent years, it was proposed to detect turbulence in the atmosphere from standard meteorological radiosoundings. The detection method relies on Thorpe sorting applied to potential temperature profiles. The sampling frequency of nowadays meteorological soundings is ~ 1 Hz, i.e. spatial resolution of $\sim 4-6$ m, making possible such a detection of turbulent overturns. A tremendous advantage of this method is that it can be applied to the very large database of radiosoundings, everywhere in the world. There exist several ways to infer dynamics quantities within the atmospheric layers detected as being turbulent. The potential temperature variance gives an estimate of the turbulent potential energy. Temperature power spectra or structure functions allows to estimates the temperature structure parameter C_T^2. The rms value of the Thorpe displacements, the so-called Thorpe scale, is a measure of an outer scale of turbulence. Also, some parameters, such as the kinetic energy dissipation rate or the buoyancy length, can be inferred by combining radar and balloon estimates.
The consistency of these turbulence parameters estimates $-$ inferred from balloon data or from the combination of radar/balloon data $-$ with the direct UAV estimates will be investigated.