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Kelvin–Helmholtz Waves during the Morning Evolution of the Turbulent Layer at Dome C, Antarctica: Regimes and Patterns

Igor Petenko[1], Giampietro Casasanta[1], Margarita Kallistratova[2], Vasily Lyulyukin[2,5], Christophe Genthon[3], Alessandro Conidi[1], Andrea Cecilia[1], Roberto Sozzi[4], and Stefania Argentini[1]
[1]Institute of Atmospheric Sciences and Climate CNR, Rome, Italy (i.petenko@isac.cnr.it)
[2]A.M. Obukhov Institute of Atmospheric Physics RAS, Moscow, 117019, Russia
[3]Laboratoire de Meteolorogie Dynamique, CNRS, Paris, France
[4]Independent Scientific Consultant, Milan, 20126, Italy
[5]Bauman MSTU, Moscow, 105005, Russia

Understanding processes of wave-turbulence interactions in stably stratified shear flows is a challenging problem in atmospheric physics and hydrography. This observational study illustrates the importance of carefully considering Kelvin–Helmholtz (KH) waves and their interaction with small-scale turbulence for an adequate description and parametrization of the stable boundary layer.

The study investigates two phenomena, traditionally discussed separately, occurring during the morning transition from stable to unstable stratification at Dome C, Antarctica. Using high-resolution sodar echograms, the simultaneous occurrence of (i) the morning rise of the inversion turbulent layer, and (ii) KH waves within this layer was observed. Regular braid-like structures associated with KH shear instabilities within the elevated turbulent layer were observed in more than 70% of days over a four-month summer period November 2014 – February 2015.

Two regimes of the morning evolution (when KH waves occurred) are identified, depending on the presence or absence of turbulence during the preceding night. The weather and turbulent conditions favoring the occurrence of these regimes are analyzed corresponding the morphology of the wind and temperature fields retrieved from an instrumented 45-m tower with six measurement levels.

Two distinct patterns of KH waves are observed: (1) quasi-periodical (with periods ≈ 8−15 min) trains containing 5−10 braids, (2) about continuous series lasting 20–60 min containing 20−80 braids. A composite shape of KH waves is determined. The periodicity of these waves is estimated to be between 20 and 70 s, and their wavelength is estimated roughly to be 100−400 m. The vertical thickness of individual braids at the wave crests ranges between 5 and 25 m. The total depth of a rising turbulent layer containing these waves varies between 15 and 120 m.

Numerical simulations face challenges in reproducing turbulent wavelike structures, particularly KHBs. Further investigation is needed to unveil the precise mechanisms driving the morning

elevation and growth of KH waves along with the developing convective layer.