Geophysical Research Abstracts
Vol. 17, EGU2015-10029, 2015
EGU General Assembly 2015

Planetary boundary layer as an essential component of the earth's climate system

Richard Davy (1,2) and Igor Esau (1,2)

(1) Nansen Environmental and Remote Sensing Center, Bergen, Norway (richard.davy@nersc.no), (2) Bjerknes Center, Bergen, Norway

Following the traditional engineering approach proposed by Prandtl, the turbulent planetary boundary layers (PBLs) are considered in the climate science as complex, non-linear, essential but nevertheless subordinated components of the earth's climate system. Correspondingly, the temperature variations, dT – a popular and practically important measure of the climate variability, are seen as the system's response to the external heat forcing, Q, e.g. in the energy balance model of the type dT=Q/C (1). The moderation of this response by non-linear feedbacks embedded in the effective heat capacity, C, are to a large degree overlooked. The effective heat capacity is globally determined by the depth of the ocean mixed layer (on multi-decadal and longer time scales) but regionally, over the continents, C is much smaller and determined (on decadal time scales) by the depth, h, of the PBL.

The present understanding of the climatological features of turbulent boundary layers is set by the works of Frankignoul & Hasselmann (1976) and Manabe & Stauffer (1980). The former explained how large-scale climate anomalies could be generated in the case of a large C (in the sea surface temperature) by the delta-correlated stochastic forcing (white noise). The latter demonstrated that the climate response to a given forcing is moderated by the depth, h, so that in the shallow PBL the signal should be significantly amplified. At present there are more than 3000 publications (ISI Web of Knowledge) which detail this understanding but the physical mechanisms, which control the boundary layer depth, and statistical relationships between the turbulent and climatological measures remain either unexplored or incorrectly attributed.

In order to identify the climatic role of the PBL, the relationships between the PBL depth, h, – as the integral measure of the turbulent processes and micro-circulations due to the surface heterogeneity – and the climatic variability (variations and trends) of temperature have to be established. These relationships are necessary to complete the model (1) where the relationships between temperature variability, dT, and heat forcing, Q, are intensively studied. We demonstrate that the statistical dependences between dT and h becomes the primary factor in controlling the climate features of the earth's climate system when h is shallow (less than about 500 m). Such conditions are found in the cold (with negative surface heat balance on average) and dry (with large-scale air subsidence) climates. To get those climates and their variations correct, the climate models must be able to reproduce the shallow stably-stratified PBL. We show that the present-day CMIP-5 models are systematically and strongly biased towards producing deeper PBLs (between 20-50% deeper than observed) in this part of the parameter space which leads to large errors (around 15 K) and a damped variability of the surface temperatures under these conditions. More generally, this bias indicates that the models represent the earth's cooling processes incorrectly, which may be a part of the puzzle of the observed "hiatus" (or pause) in global warming.

Frankignoul, C. & K. Hasselmann, 1977: Stochastic climate models. Part 2, Application to sea-surface temperature anomalies and thermocline variability, Tellus, 29, 289-305.

Manabe, S. & R. Stouffer, 1980: Sensitivity of a Global Climate Model to an increase of CO_2 concentration in the atmosphere, Journal of Geophysical Research, 85(C10): 5529-5554.