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Modelling of the diurnal variation of the global electric circuit with a new parameterisation of the ionospheric potential using CAPE

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The state of the global electric circuit (GEC) depends on both terrestrial and space weather and climate, which causes a great interest in GEC modelling, including prognostic simulations of GEC and lightning trends with changing climate. Over the past decade, several new models of the GEC, based on various approaches and descriptions, have appeared. In this connection the parameterisation of the main parameters characterising the state of the GEC, in the first place the ionospheric potential (IP), remains one of the most principal problems related to GEC modelling.

In this study, following the ideas of Mareev and Volodin [2014], a new IP parametrisation is developed for global forecasting models of the atmospheric dynamics and applied in calculations using the forecasting model WRF (Weather Research and Forecasting Model) running globally. The developed parameterisation is based on a formula expressing the IP in terms of a given distribution of charge separation currents in the atmosphere under the assumption that the conductivity grows exponentially with increasing height. The lower and upper boundaries of the charge separation region inside a cloud are determined by the isotherms 0 °C and −38 °C, and the area occupied by convection in each grid column is determined by dividing the amount of precipitation by the total amount of precipitable water.

To single out electrified clouds, which operate as GEC generators, an approach based on computing convective available potential energy (CAPE) is used. Areas characterised by shallow convection with relatively small CAPE values (e.g., not exceeding 1 kJ kg^{-1}) are not taken into account, which turns out to be important for obtaining a correct picture of the IP diurnal variation. At the same time, the nature of the dependence of charging currents in deep convection clouds on the CAPE value does not affect the appearance of the diurnal variation curve.

The developed IP parameterisation gives a reasonable diurnal variation of the IP, qualitatively consistent with the classical Carnegie curve with an accuracy of a certain displacement of local maxima and minima within 1 to 2 hours. At the same time, the total maximum to minimum variation of the model curve is smaller than that in the classical Carnegie curve.

It is interesting to note that the obtained parameterisation is similar in its nature to the parameterisation suggested by Romps et al. [2018] for the lightning flash rate over land. However, our parameterisation describes the IP rather than the flash rate, has a clear physical basis and can be applied to both land and oceans.

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References

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